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Rotorcraft Low Altitude IFR Benefit/Cost Analysis:

Conclusions and Recommendations

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Final Report

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16. Abstract The Rotorcraft Master Plan advocates the establishment of additional communications, navigation, and surveillance (CNS) facilities, as well as the analysis and development of systems to satisfy the increasing demand for widespread instrument flight rules (IFR) rotorcraft operations within the National Airspace System (NAS). The objective of this study is to determine if there is an economic basis for improvement of these low altitude IFR services within the NAS in order to better support rotorcraft IFR operations. The findings of this study will aid FAA decision making in that regard. In view of prior implementation decisions on LORAN-C and GPS, the emphasis in this effort is on communications, surveillance, procedural changes, and avionics.

This report is the last of a series of three reports that address rotorcraft low altitude benefit/cost analysis. The other two are:

1) Rotorcraft Low Altitude CNS Benefit/Cost Analysis: Operations Data, DOT/FAA/DS-89/9, and
2) Rotorcraft Low Altitude IFR Benefit/Cost Analysis: Operations Analysis, DOT/FAA/RD-89/10.

This final report reviews the operational requirements and constraints for specific rotorcraft missions identified in the previous reports in this series. It also reviews all of the alternatives identified for improving rotorcraft operations. The alternatives considered include additional communications and surveillance equipment, both existing equipment and future systems identified in the Aviation Systems Capital Investment Plan (CIP), and the air traffic control (ATC) procedu changes. A benefit/cost (B/C) analysis is conducted for each communication, surveillance, and procedural improve. identified. When site specific data is available, it is used to calculate actual B/C ratios. When no data exists, a break-even analysis is provided.

17. Key Words

Benefit/Cost	Helicopter Operations
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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1.0 INTRODUCTION

This report recommends improvements to low altitude communications, navigation, surveillance (CNS) capabilities and air traffic control (ATC) procedures to satisfy rotorcraft operational needs. It addresses existing and future needs of rotorcraft operating in the National Airspace System (NAS) and recommends solutions that require capital expenditures to implement. It further evaluates the solutions with a benefit/cost analysis of 50 sites located throughout the United States. The findings of this study are designed to aid the Federal Aviation Administration (FAA) in decision making concerning the procurement and implementation of new services, procedures, and equipment.

This document is the final report in a series of three reports that address rotorcraft low altitude CNS. The first report, "Rotorcraft Low Altitude CNS Benefit/Cost Analysis: Rotorcraft Operations Data," DOT/FAA/DS-89/9, September 1989, provides background data on the rotorcraft industry as it exists today and forecasts rotorcraft activities to the year 2007. Descriptions and details of pertinent rotorcraft missions and an inventory of rotorcraft activity by mission and location are also included.

The second report, "Rotorcraft Low Altitude IFR Benefit/Cost Analysis: Operations Analysis," DOT/FAA/DS-89/10, December 1991, defines operational requirements and constraints on selected rotorcraft missions, lists 50 sites in the United States where rotorcraft are most likely to benefit from improvements, addresses improvements to the NAS, and provides a benefit/cost methodology for assessing the improvements.

This final report summarizes the pertinent information from the preceding two documents, applies the benefit/cost methodology to 50 United States sites, and provides recommendations for incorporation of rotorcraft requirements for improved IFR services into the Aviation System Capital Investment Plan (CIP) (reference 1).

In recent months, two key benefit/cost analysis parameters have changed. First, the Office of Management and Budget has lowered the discount rate from 10 to 7 percent (see reference 32). Second, the Office of the Secretary of Transportation has directed that the value of life used in DOT benefit/cost analysis should be increased from \$1.5 million to \$2.5 million (see reference 33). The calculations in this document were done with the old values. Thus, they will tend to understate the net benefits associated with providing the evaluated services.

The impact of the change in discounting rate will be moderate - benefits will increase by a factor of about 1.2 depending on circumstances. The increase in the value of life will have the impact of raising Emergency Medical Services (EMS) benefits by a factor of about 1.67. Those who wish to apply the methodologies

of this document for other geographical locations should use these revised values in their benefit/cost analysis. Together, the changes in these two parameter could double the benefit/cost ratios for EMS benefits.

2.0 BACKGROUND

Rotorcraft operational needs frequently are either not addressed or only briefly discussed in investigations that recommend both short- and long-term improvements to the NAS. This lack of consideration was defendable when rotorcraft flight time historically comprised less than 1 percent of the annual flight hours in the United States. Rotorcraft flights have also traditionally been perceived as being conducted outside of controlled airspace and rotorcraft pilots have been thought to need minimal ATC services.

Such a concept of rotorcraft operations is no longer accurate as the civilian rotorcraft community has over the last decade both increased in volume and undergone evolutionary change. Rotorcraft flight hours have increased at an annual rate of 7.0 percent in the years 1982 to 1988 (reference 2). Equally important is the expanded instrument flight rules (IFR) capability rotorcraft that operators are acquiring and the prominent societal role they are now fulfilling (reference 3).

In numerous missions, rotorcraft are performing substantial lifesaving and transportation roles. Rotorcraft support emergency medical services (EMS) in virtually all areas of the United States. Offshore rotorcraft operators perform 1,000 operations per day (reference 4). Hundreds of air taxi, business, and corporate/executive flights are performed daily (reference 5), and in the future, rotorcraft commuter services may provide as much as 10 percent of intercity passenger air-transportation (reference 2).

The rotorcraft industry's maturation and forecasted continued strong growth indicate that the FAA should consider rotorcraft operators' needs in NAS improvement plans. Rotorcraft have different flight capabilities and limitations than fixed-wing aircraft and often perform unique missions. These differences result in some operational needs that are unique. This report develops an understanding of these unanswered needs, recommends solutions, and concludes with a justification of these solutions based on a benefit/cost analysis.

Both equipment and procedural improvements are recommended. To provide a basis for these recommendations, more than a gross comparison of all potential improvements to the NAS was needed. Therefore, three requirements were placed on the potential improvements that were analyzed: (1) an investment of capital is required, (2) it should adequately satisfy a rotorcraft user requirement, and (3) the improvement must not be so visionary as to require radical changes in existing Federal Aviation Regulations (FARs). These constraints enabled the investigation to be more focused and achieve its final objectives.

Studies such as this one are difficult to document because they must, by necessity, postulate on an evolving air traffic control system, forecast trends in future operations and user needs, and assess the

impact and useability of future technology. This difficulty was compounded by the lack of readily available data on site-specific rotorcraft operations. To constrain the study and facilitate its completion, four assumptions about rotorcraft operations and the NAS were made:

(1) Programs contained in the 1990 CIP, except those in chapter 6, New Capabilities, will occur as scheduled and all associated costs are considered sunk.

(2) Rotorcraft will continue to operate under either visual flight rules (VFR), special VFR (SVFR), or instrument flight rules (IFR) according to the existing FARs, existing average rotorcraft instrument approach weather minimums, and the recommended VFR weather minimums contained in the EMS/helicopter advisory circular (reference 6).

(3) Existing FARs and air traffic control procedures will not undergo major changes, although technological advances will allow innovative solutions to air traffic control problems.

(4) Rotorcraft en route navigational needs will be fully met with the completion of the long range navigation (LORAN-C) chains and the global positioning satellite (GPS) constellation (discussed in section 4.2).

This report documents research into numerous FAA programs and rotorcraft missions throughout the country. The methodology used to conduct this research is shown in figure 1. The sequence of investigation was to first identify rotorcraft operational needs and then understand planned and potential improvements to the NAS. With this information, rotorcraft-specific improvements are recommended and a benefit/cost analysis is used to validate their feasibility.

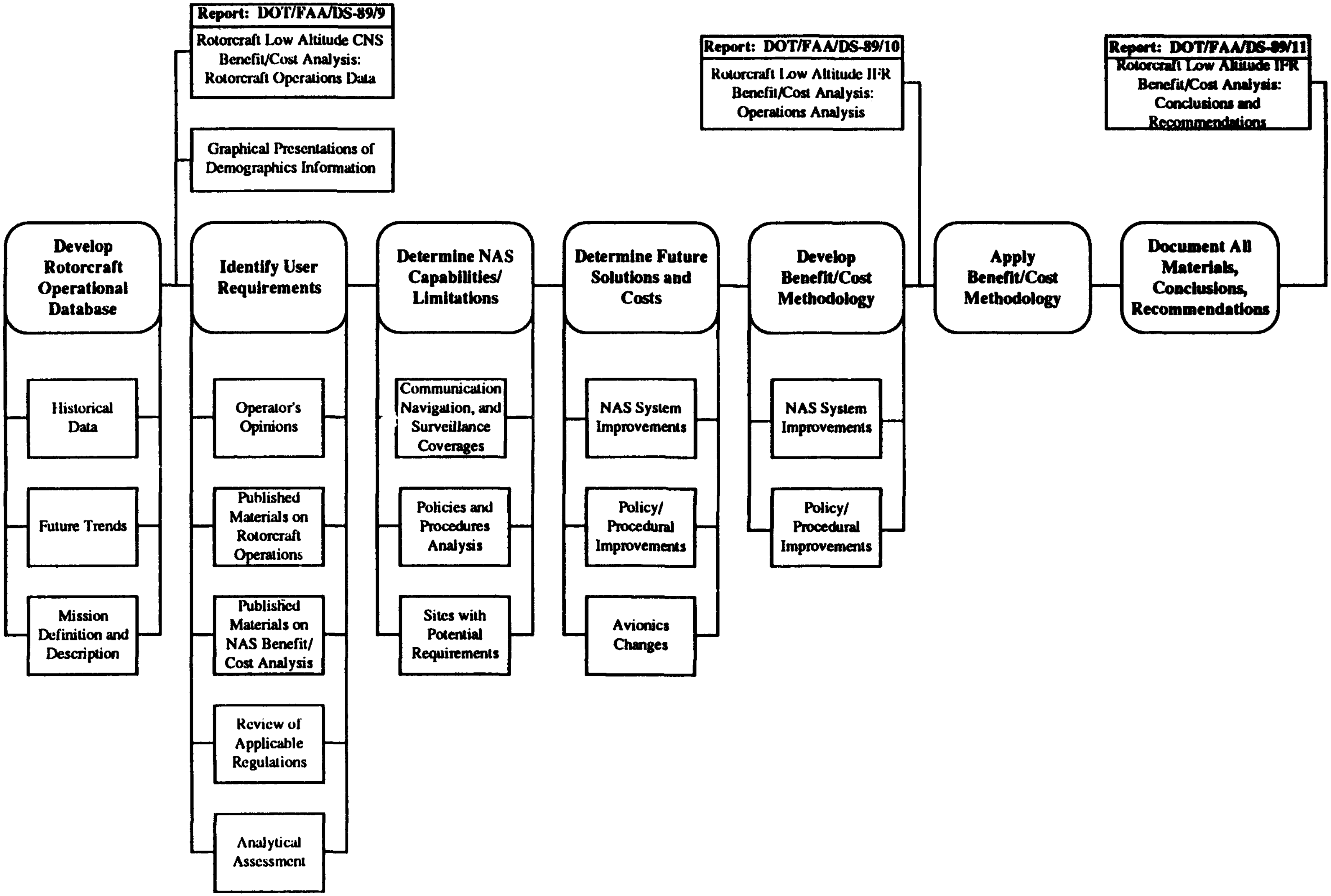


FIGURE 1 ROTORCRAFT LOW ALTITUDE IFR BENEFIT/COST ANALYSIS - STUDY METHODOLOGY

3.0 ROTORCRAFT OPERATIONAL REQUIREMENTS

An understanding of the differences between the operational requirements of rotorcraft and fixed-wing aircraft is an important element of this investigation. The following sections describe the unique characteristics, capabilities, and limitations of rotorcraft, applicable FARs, and mission specific data. This information is then related to rotorcraft operational requirements.

3.1 ROTORCRAFT FLIGHT CHARACTERISTICS

Rotorcraft hold both important advantages and disadvantages over fixed-wing aircraft. The primary advantages of rotorcraft are their vertical/short takeoff and landing (VSTOL) and slow airspeed capabilities. These characteristics enable rotorcraft to operate in areas where fixed-wing aircraft cannot and largely justify their existence. These capabilities are the prime areas of interest in this investigation, as they contribute to rotorcraft operational difficulties within the NAS and served to identify areas to focus the study.

The primary disadvantages of rotorcraft with respect to fixed-wing aircraft are their diminished performance in airspeed, payload, range, and their higher operating costs per passenger/payload. These inherent limitations typically exclude rotorcraft from competing with fixed-wing aircraft over anything other than short and medium distances or to and from locations that lack runways.

Helicopter payload weights and sizes are typically less than their fixed-wing counterparts in the same price range. For example, the Bell 206B3 (Bell Jet Ranger) has a maximum payload weight of 480 pounds on a 95 degree day at sea level (with a pilot and full fuel). The addition of extra avionics (i.e., high-frequency radio or terminal collision avoidance systems (TCAS)) can reduce payload weight capacity by another 10 percent. Additional weight will also adversely impact fuel consumption and confined area departure capabilities. Even small configuration modifications must be taken into account with respect to the intended mission requirements.

The higher variable operating costs of rotorcraft are another reason pilots are reluctant to incur any unnecessary delays. Helicopter variable operating costs (fuel, oil and maintenance) are typically three times greater than an airplane of similar weight (reference 8).

When rotorcraft operate IFR while en route, their flight characteristics are not especially unique when compared to fixed-wing aircraft. In general, en route IFR airspeeds for rotorcraft range from 90 to 150 knots which is not significantly slower than airplanes that operate at similar altitudes. Standard rates of turn, climb/descent rates, and pilot procedures are similar to fixed-wing aircraft. FAR requirements are also similar. Rotorcraft are, however, slower than most business aircraft that fly IFR at higher altitudes.

Any additional distances can result in disproportionate increases in flight time with respect to other commercial aircraft. Therefore, when rotorcraft are forced to fly unnecessary additional distances, the effects can be especially economically disruptive.

When rotorcraft conduct IFR approaches and departures, they have significantly more capability than fixed-wing aircraft. Rotorcraft are defined as Category A aircraft (less than 91 knots) for instrument approaches, thereby enabling the lowest published weather minimums to be used. An additional exception allows visibility requirements to be further reduced. Design requirements for rotorcraft-only instrument approaches also contain several important provisions. These provisions can effectively lower the ceiling and visibility requirements for many approaches and enable them to be located where standard instrument approach procedures (SIAP) would be useless (reference 9).

FAA regulations contain numerous exceptions that take into account rotorcraft's slow airspeed and VSTOL capabilities. These exceptions primarily benefit VFR operations and have eliminated many otherwise confining restrictions. As a result, rotorcraft are able to operate VFR with low ceilings and visibility and remain separated from normal traffic flows in terminal areas. The benefits to IFR rotorcraft operations exist only in terminal areas and arise from less restrictive terminal instrument procedures (TERPS) requirements and reduced weather minimums on instrument approaches. FARs that directly impact rotorcraft flights are presented in appendix A. An understanding of their effects on rotorcraft flights is essential to this investigation.

3.2 ROTORCRAFT OPERATIONAL ISSUES

Several rotorcraft operational issues are common to most operators regardless of mission. These requirements are presented below. Mission specific requirements are presented in the following section.

3.2.1 Update of Growth Rate Projections

The rates of growth for both the rotorcraft fleet and number of flight hours were projected in the first interim report to be 2.7 percent for almost all rotorcraft mission types. The two exceptions to the 2.7 percent growth rate were for the scheduled commuter mission, which had a projected growth rate of 3.7 percent, and the EMS mission, which had a projected growth rate starting at 6.5 percent in 1989 and declining thereafter. Another projection of rotorcraft growth rates was prepared by the Applied Systems Institute (ASI) for the FAA Office of Aviation Policy and Plans. Both projections are described in detail in the first interim report. As will be seen in the following paragraphs, the 2.7 percent growth rate projection has been fairly accurate for the last 3 years. All data comes from the "General Aviation Pilot and Aircraft Survey" published annually by the FAA, unless otherwise cited. Figure 2 shows FAA historical data on the

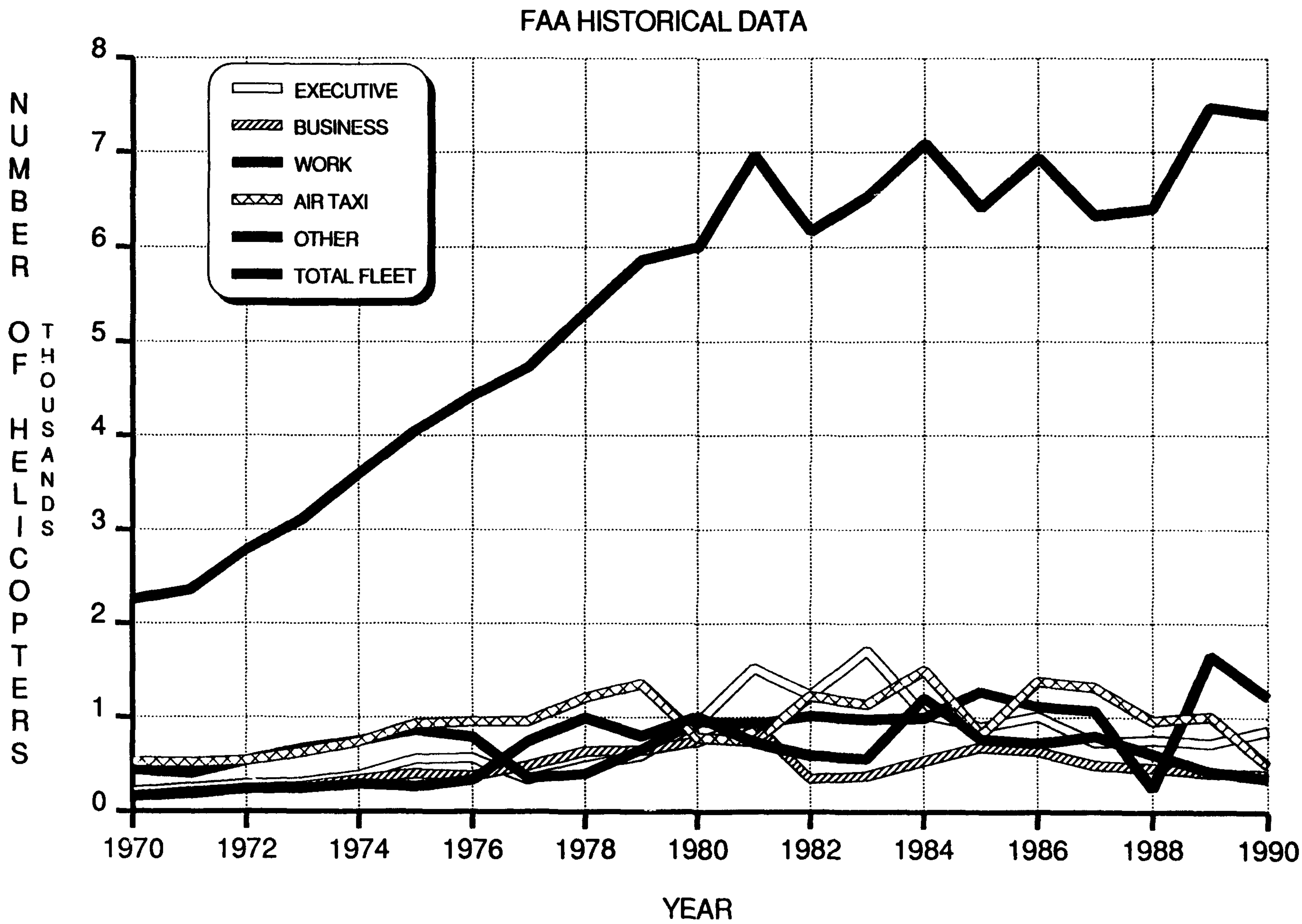


FIGURE 2 FLEET SIZE FORECAST

number of rotorcraft in the civil fleet by mission type and for all missions. Figure 3 shows FAA historical data on rotorcraft flight hours from 1970 through 1989 by mission type and for all rotorcraft. In the "FAA Aviation Forecasts Fiscal Years 1992 - 2003," the projection for the number of active helicopters in the year 2003 is 10,800 helicopters. The methodology developed in the first interim report projects 10,600 active helicopters in the year 2003. Thus, the two methods are in agreement to within 2 percent.

3.2.1.1 EMS Mission Forecasts

Figures 4 and 5 show the projected number of flight hours and number of rotorcraft for the EMS mission, respectively. Both of these graphs show the EMS mission to be expanding at the most likely estimate of growth. The projected growth rate for the EMS industry is predicted to decline over the next 15 years for the following reasons: 1) the EMS industry is becoming more mature and there are fewer new hospitals/operators starting new programs, and 2) payment restrictions on medicare payments for helicopter transports are discouraging many hospitals from providing helicopter EMS. The first interim report (reference 5) contains a complete discussion of the projected growth of the EMS mission. ASI did not make projections on the growth of the EMS mission.

3.2.1.2 Corporate/Executive Mission Forecasts

Figures 6 and 7 show the projected number of flight hours and number of rotorcraft for the corporate/executive mission, respectively. Both of these graphs show the corporate/executive mission to have grown about as expected, possibly slightly slower than the most likely estimate. The data points for 1988 through 1990 bracket the projected growth curves developed in this report. The projections developed by ASI are slightly low in both cases. The recession of 1991 will probably result in lower numbers for both number of aircraft and flight hours in 1991.

3.2.1.3 Scheduled Commuter Mission Forecasts

The growth rate projected for the scheduled commuter mission is 3.7 percent. Figures 8 and 9 show the projected number of flight hours and number of rotorcraft for the scheduled commuter mission, respectively. Both of these graphs show a large variance from one year to the next. The data for 1989 shows the commuter mission to be growing slightly faster than the low estimate, while the 1988 and 1990 data is over four times higher than predicted in both cases. The large variations in reported data result from the small number of commuter operators. In statistical analysis, small sample size leads to large variation and low confidence in the accuracy of the data. With such large variations in the data, it is impossible to comment on the growth in the commuter mission in the last 2 years. However, in 1989, the year in which historical data coincides almost exactly

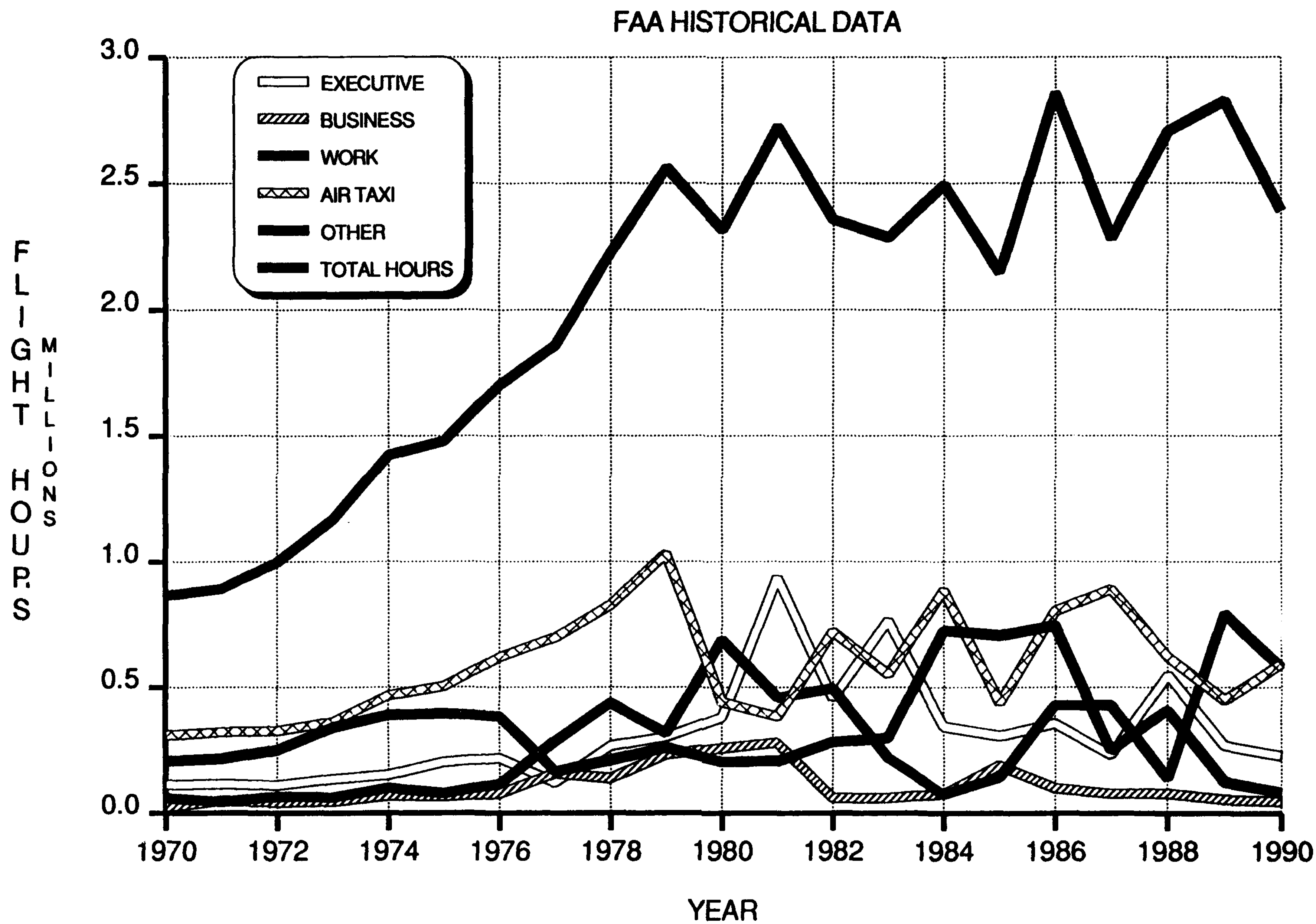


FIGURE 3 FLIGHT HOUR FORECAST

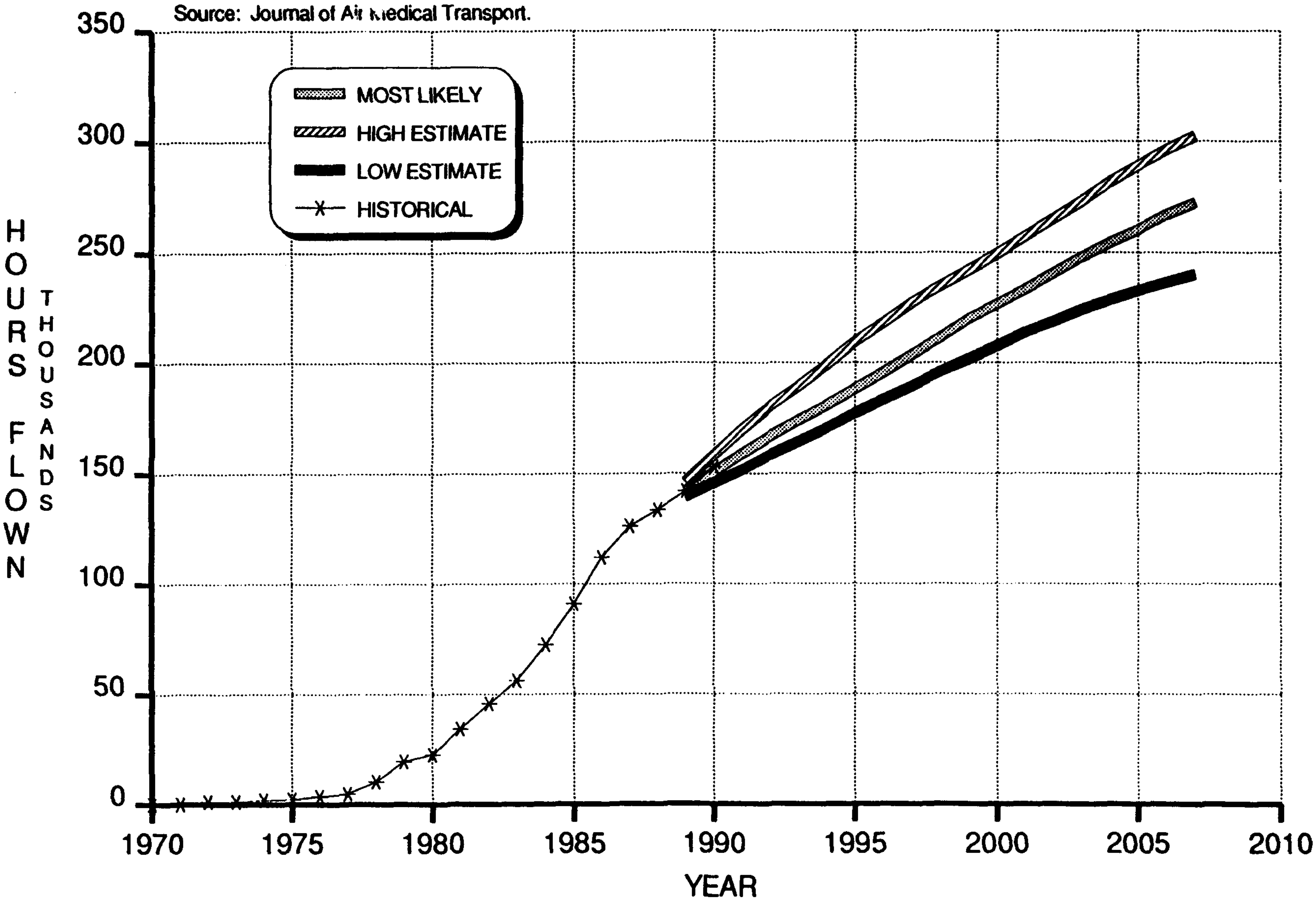


FIGURE 4 EMS FLIGHT HOUR FORECASTS

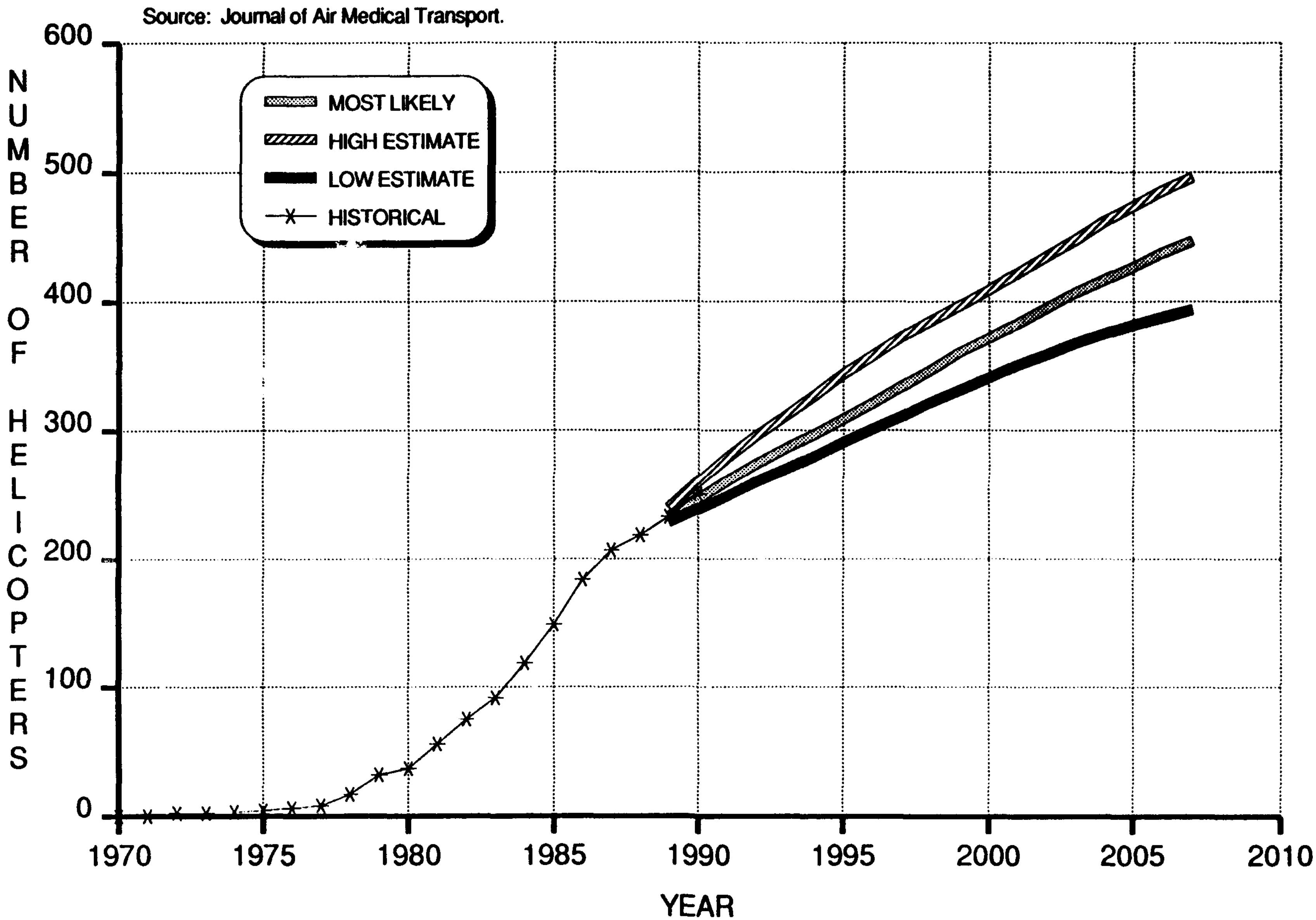


FIGURE 5 EMS FLEET FORECASTS

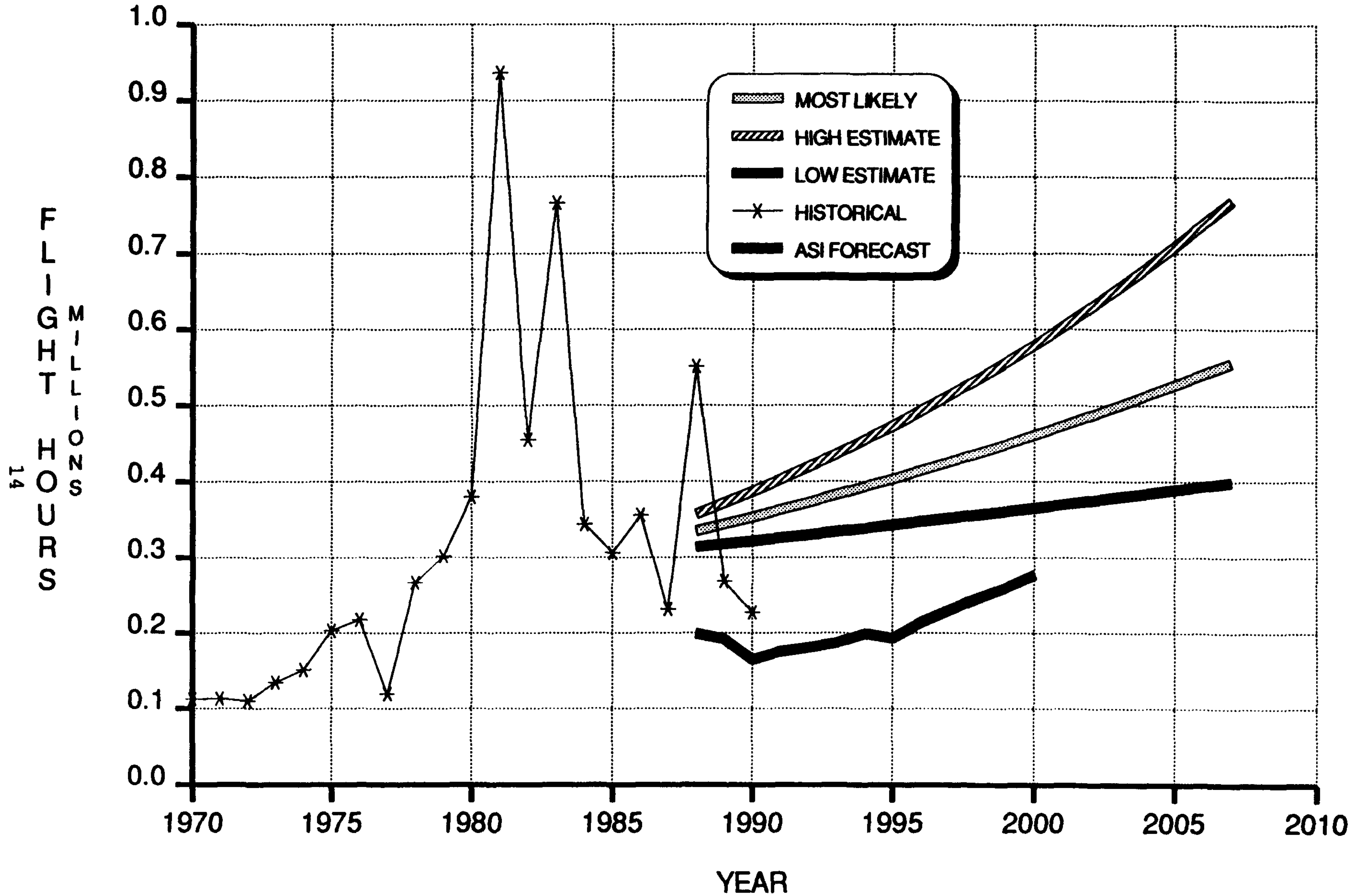


FIGURE 6 CORPORATE/EXECUTIVE FLIGHT HOUR FORECASTS

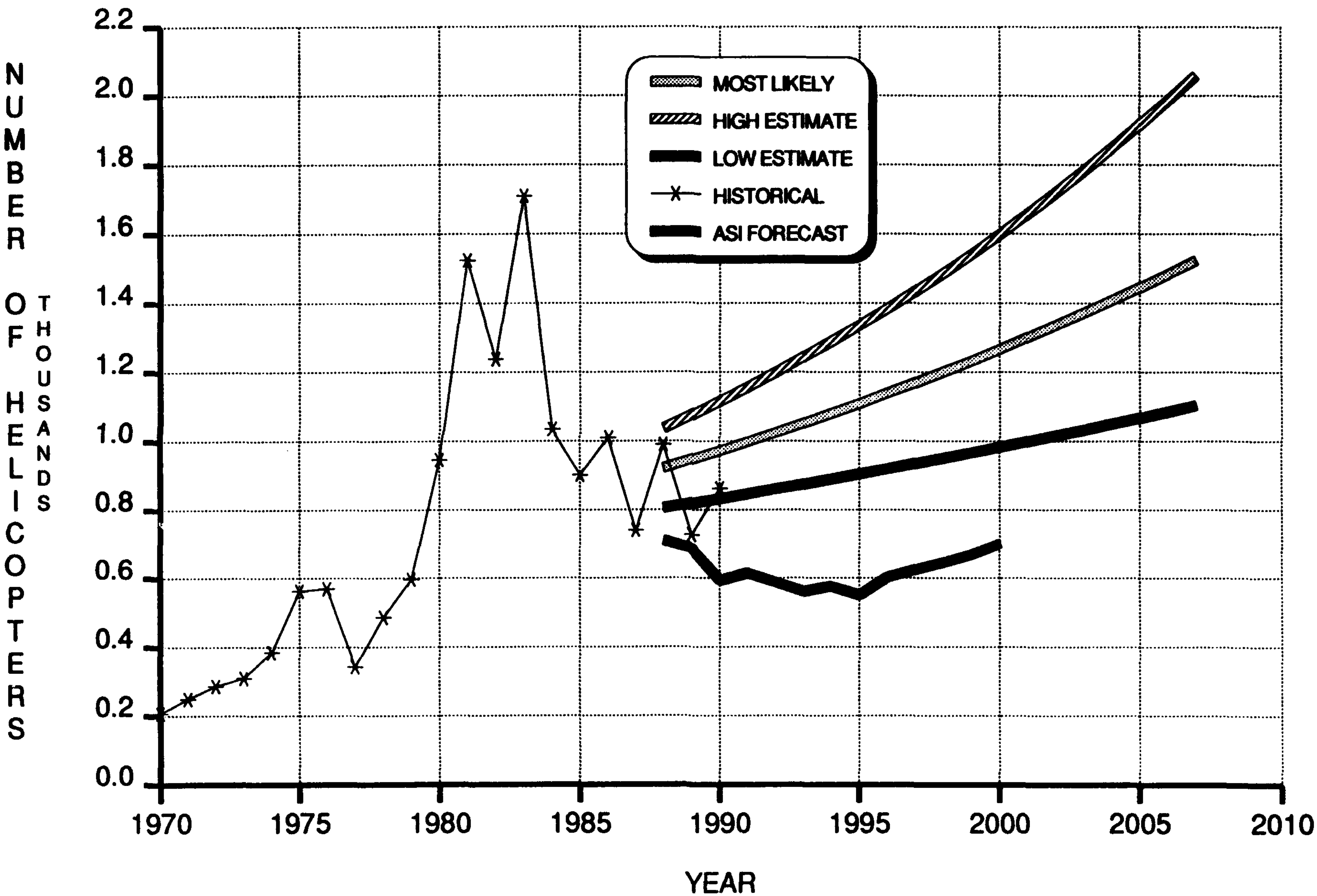


FIGURE 7 CORPORATE/EXECUTIVE FLEET FORECASTS

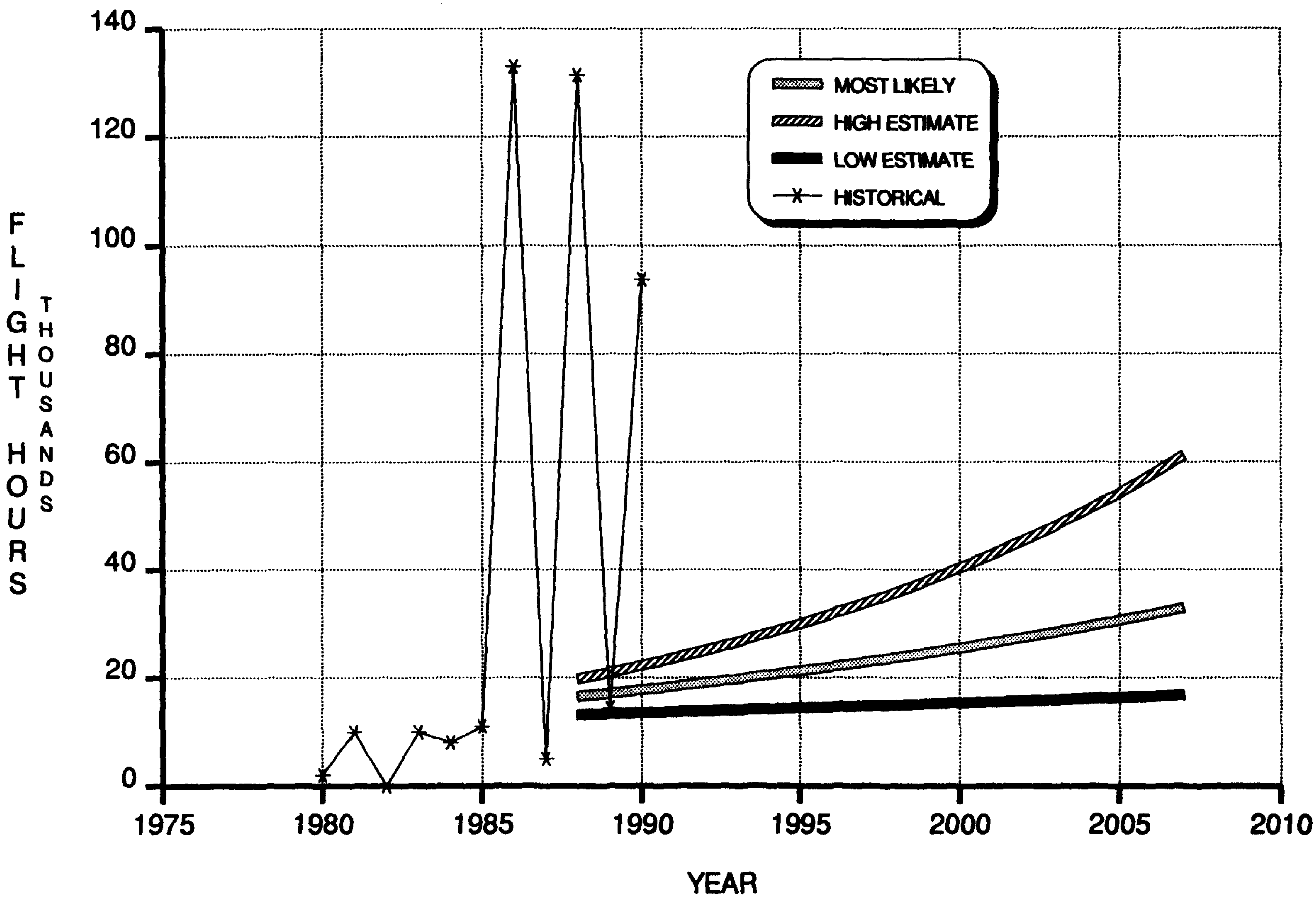


FIGURE 8 SCHEDULED COMMUTER FLIGHT HOUR FORECASTS

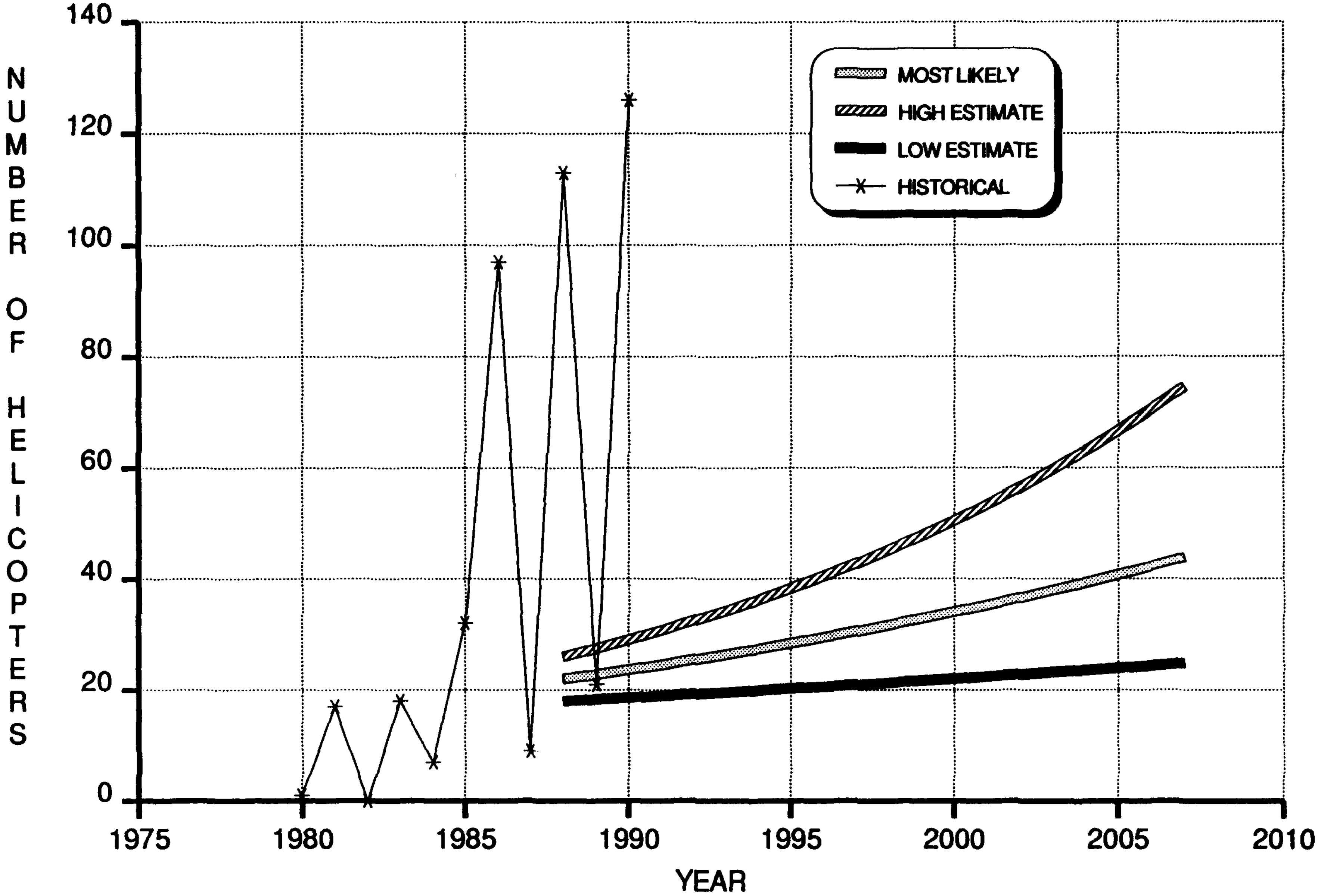


FIGURE 9 SCHEDULED COMMUTER FLEET FORECASTS

with the most likely estimate of aircraft and flight hours, the FAA attempted to do a 100 percent survey of rotorcraft operators. Therefore, some confidence may be placed in the projections made in the first interim report.

3.2.1.4 Offshore Mission Forecasts

The first interim report projected a growth rate for the offshore mission of 2.7 percent through 1995 and 3.7 percent for 1996 through 2007. Figure 10 shows that flight hours for the offshore mission have been increasing at approximately the high estimate of 4.1 percent. However, the number of flight hours in 1990 was probably affected by the large increase in the price of oil in 1990 due to the Persian Gulf crisis. The most likely long-term growth rate is still believed to be 2.7 percent. The 4.1 percent growth rate corresponded well with the ASI estimate of number of flight hours. Figure 11 shows that fleet size has been increasing at the projected 2.7 percent rate. The ASI estimates for fleet growth are very similar to the ones developed in this report.

3.2.1.5 Business Mission Forecasts

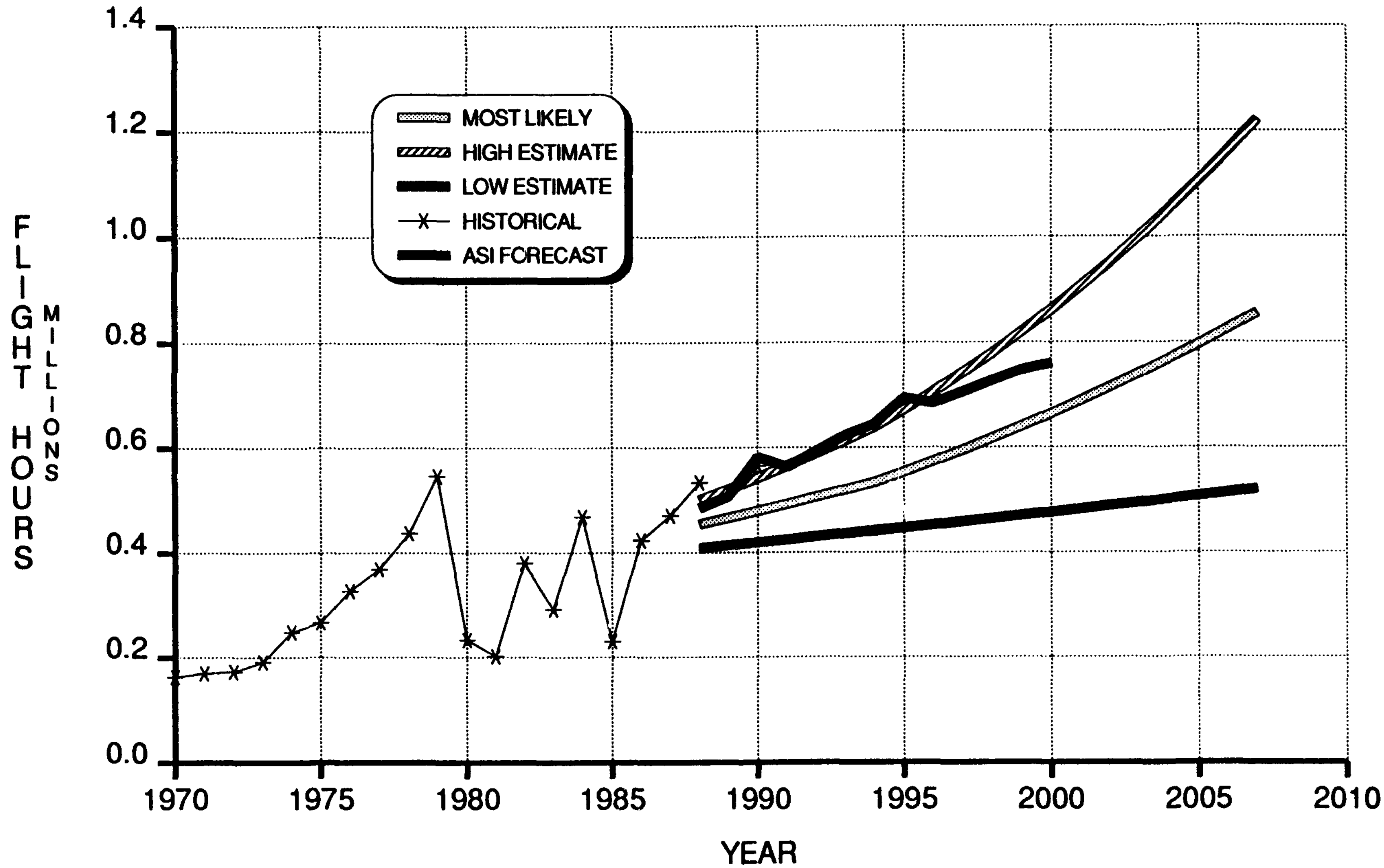
Figures 12 and 13 show the number of flight hours and fleet size for the business mission, respectively. These graphs show the business mission to be growing slightly slower than the projected 2.7 percent annual rate, although it is still premature to draw any conclusions. However, the recession of 1991 will probably keep activity below the projected level for both fleet size and flight hours. The ASI forecast greatly overestimated the number of flight hours and aircraft in this mission.

3.2.1.6 Air Taxi Mission Forecasts

Figures 14 and 15 show the number of flight hours and fleet size for the air taxi mission, respectively. Flight hours seem to be increasing at a slightly slower rate than the projected 2.7 percent. However, the wide variations from year to year make any generalizations premature. Fleet size seems to be increasing at the most likely rate of 2.7 percent. The ASI forecast slightly overestimated the number of flight hours, but did accurately forecast the number of aircraft.

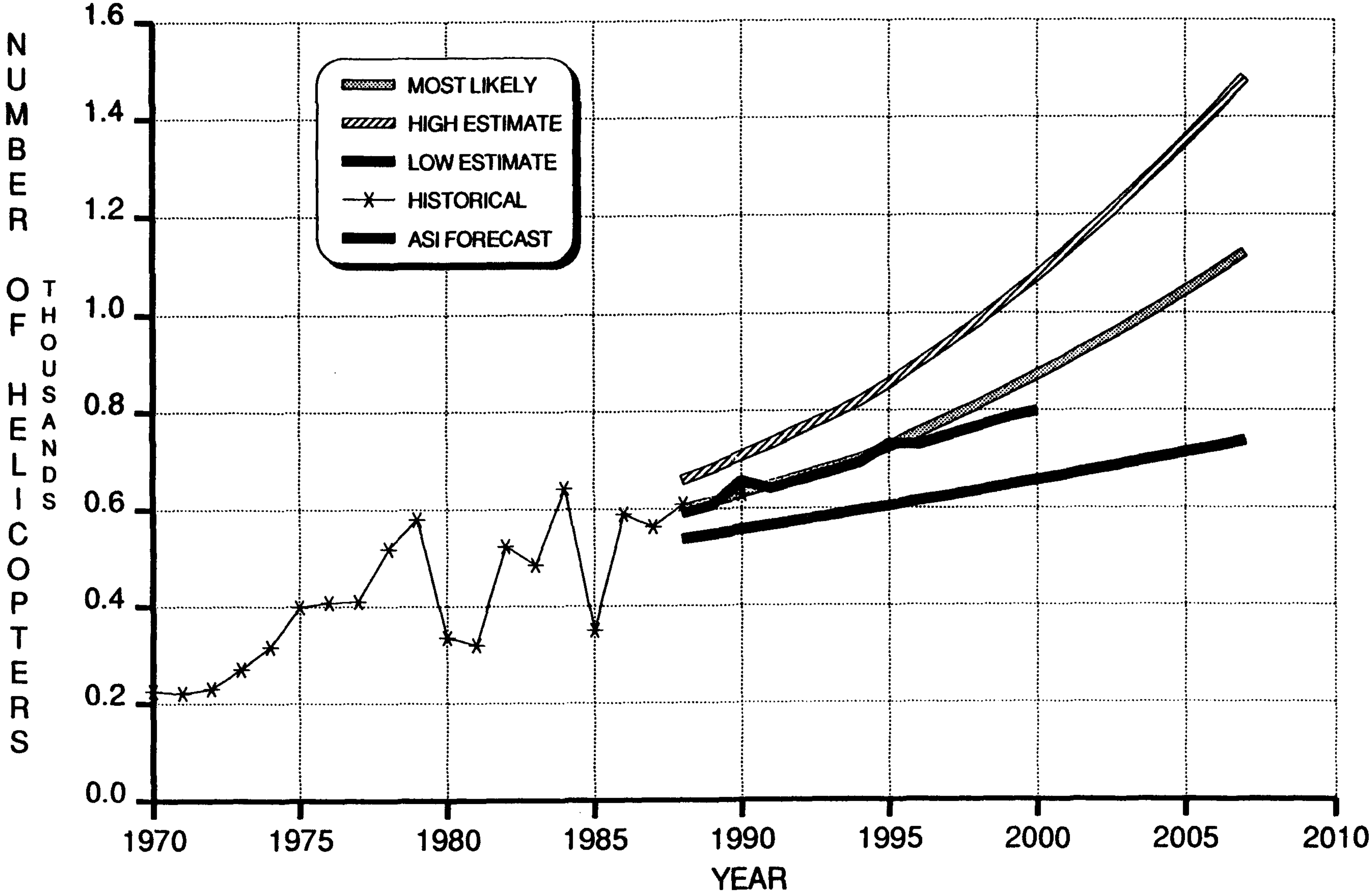
3.2.2 Rotorcraft Accident Rates

Rotorcraft accident rates have historically been higher than fixed-wing accident rates on a flight-hour basis. A comparison of these rates for the years 1964 through 1989 is presented in figure 16. Rotorcraft accident rates have improved to the point where they now equal general aviation fixed-wing rates. Rotorcraft accident rates have decreased at an average annual rate of 6.3 percent from 1979 to 1989. Extrapolating this trend to the year 2000 would result in an accident rate of 3.6 accidents per 100,000 hours (reference 25).



NOTE: Offshore Part 135 operations as reported by HSAC and Rotor & Wing International.

FIGURE 10 OFFSHORE FLIGHT HOUR FORECASTS



NOTE: Offshore Part 135 operations as reported by HSAC and Rotor & Wing International.

FIGURE 11 OFFSHORE FLEET FORECASTS

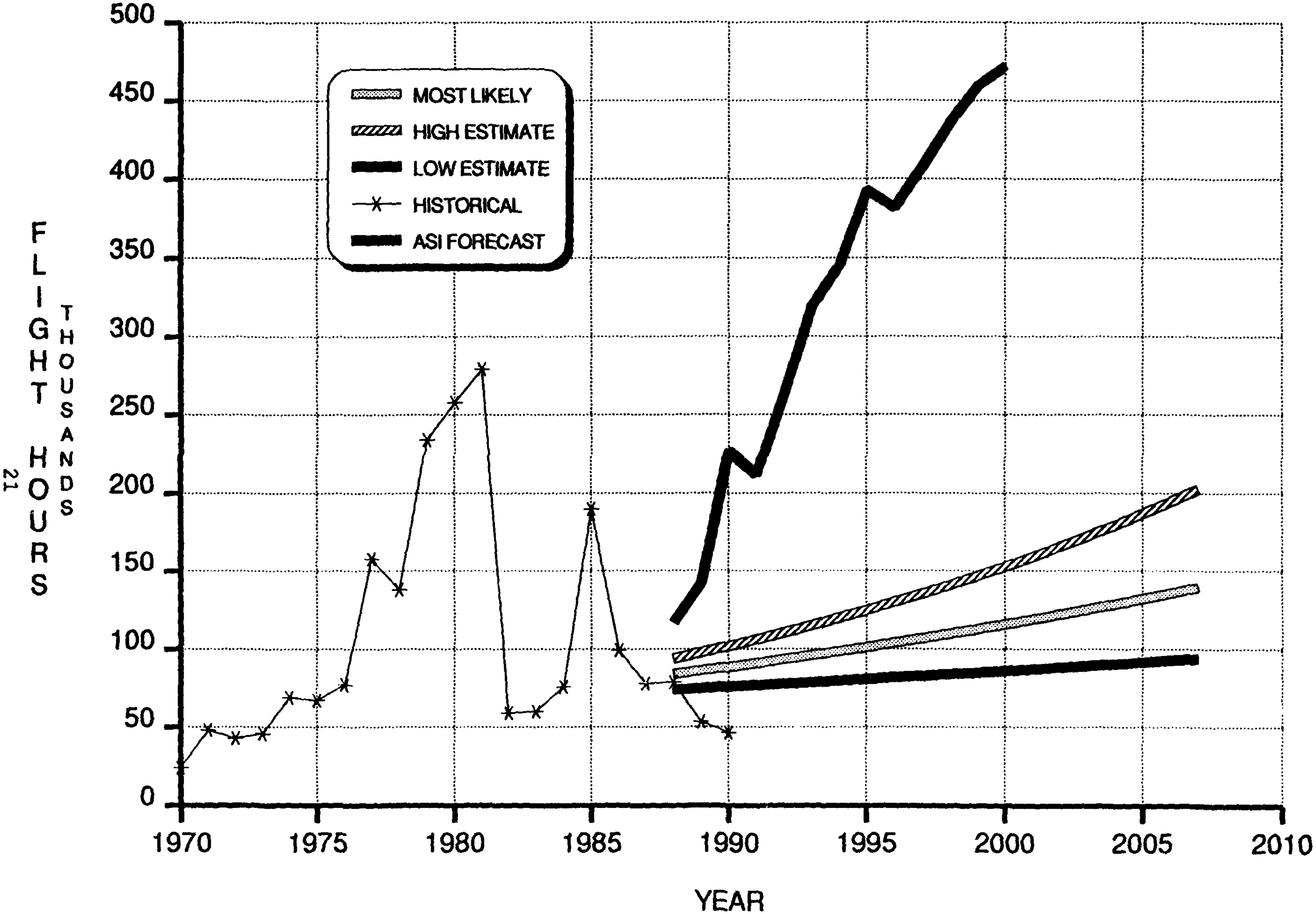


FIGURE 12 BUSINESS FLIGHT HOUR FORECASTS

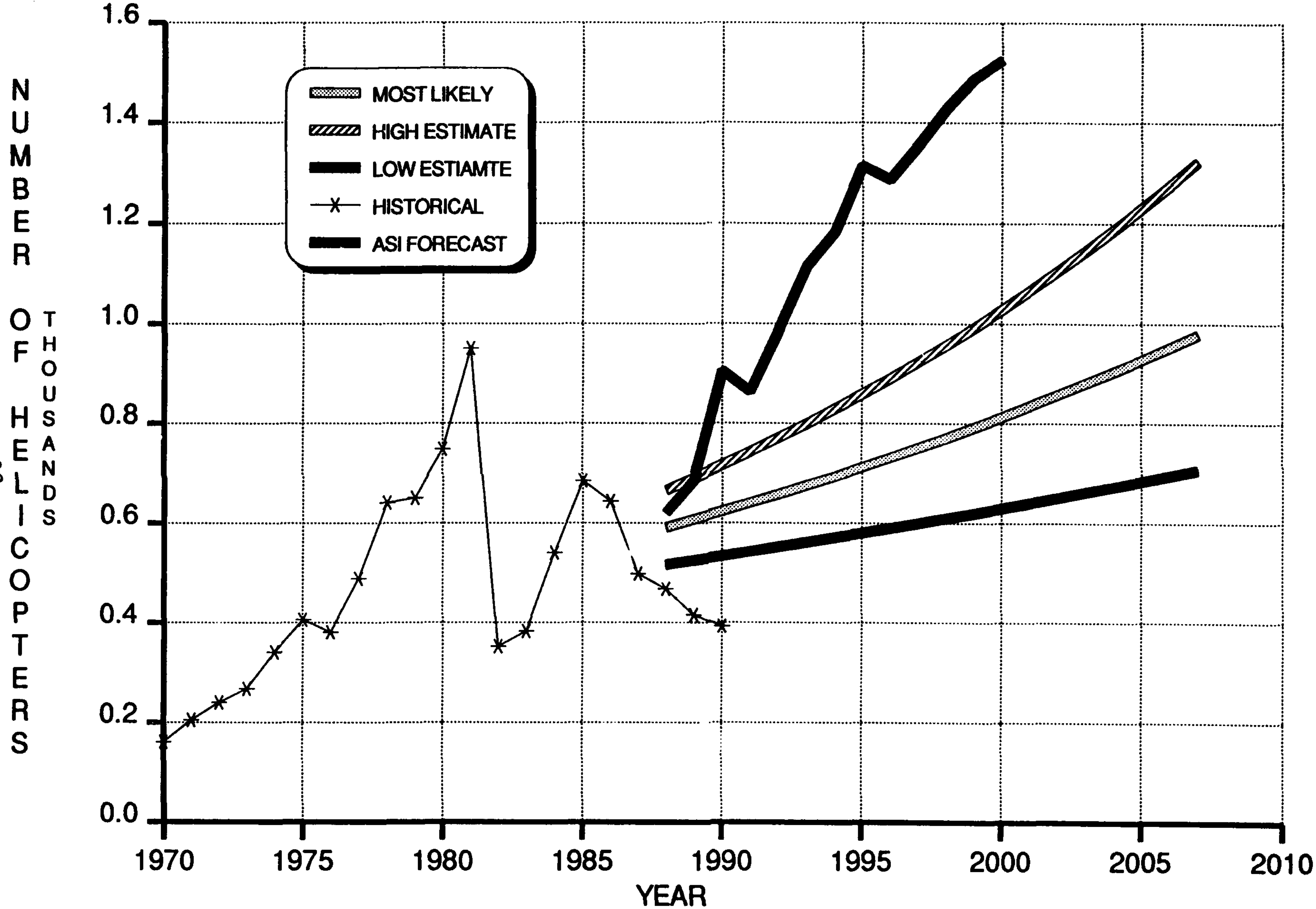
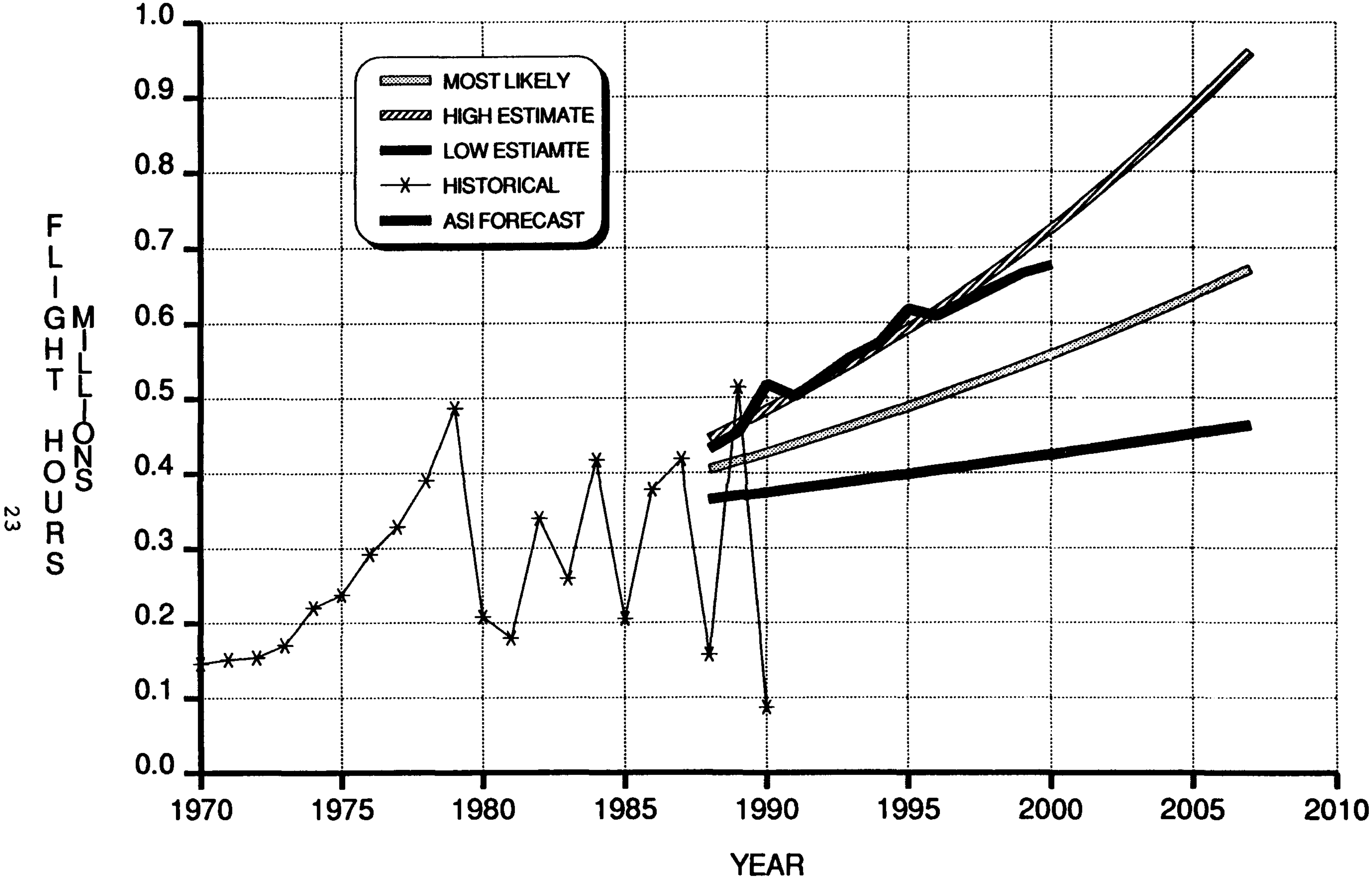
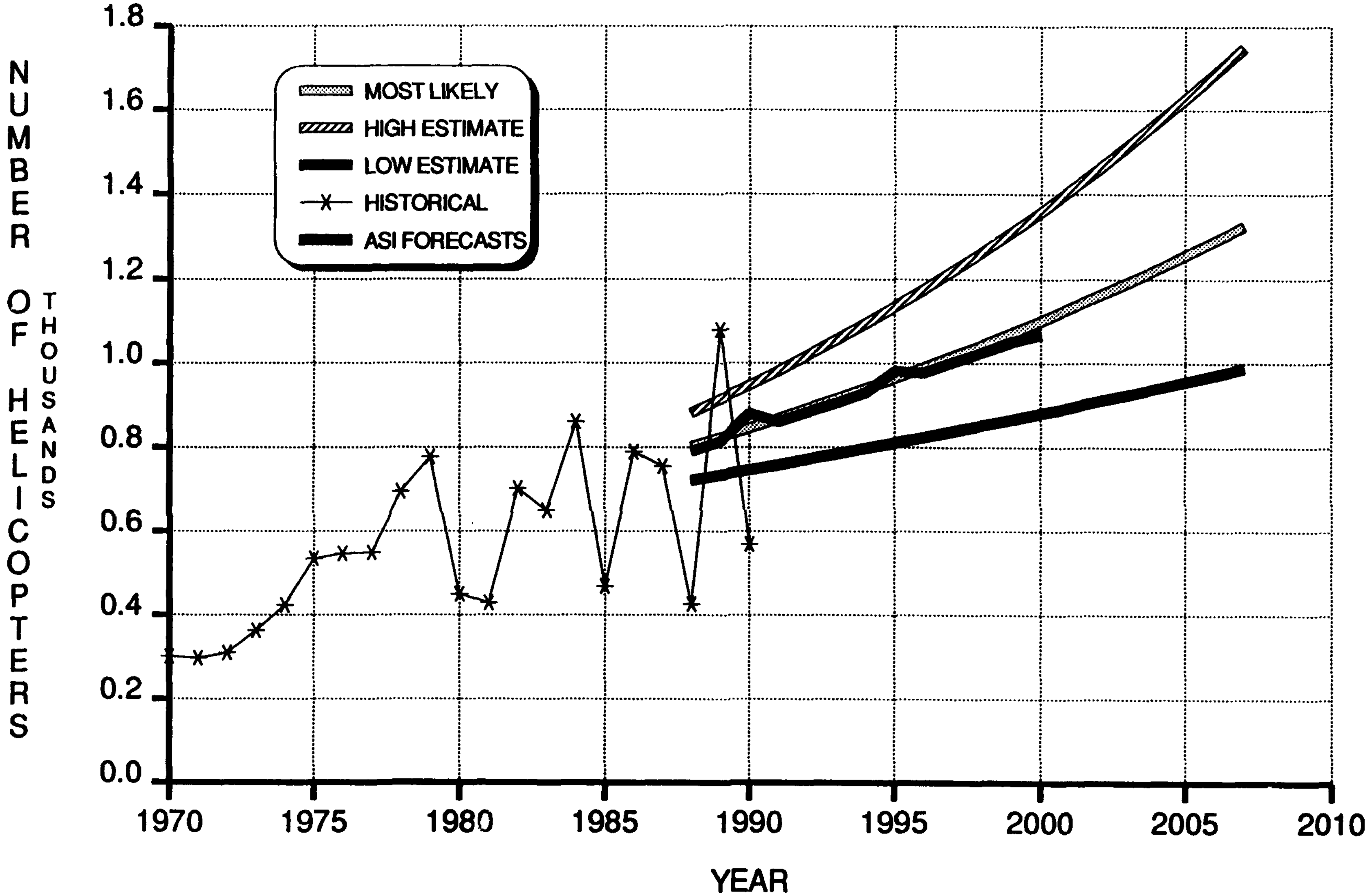


FIGURE 13 BUSINESS FLEET FORECASTS



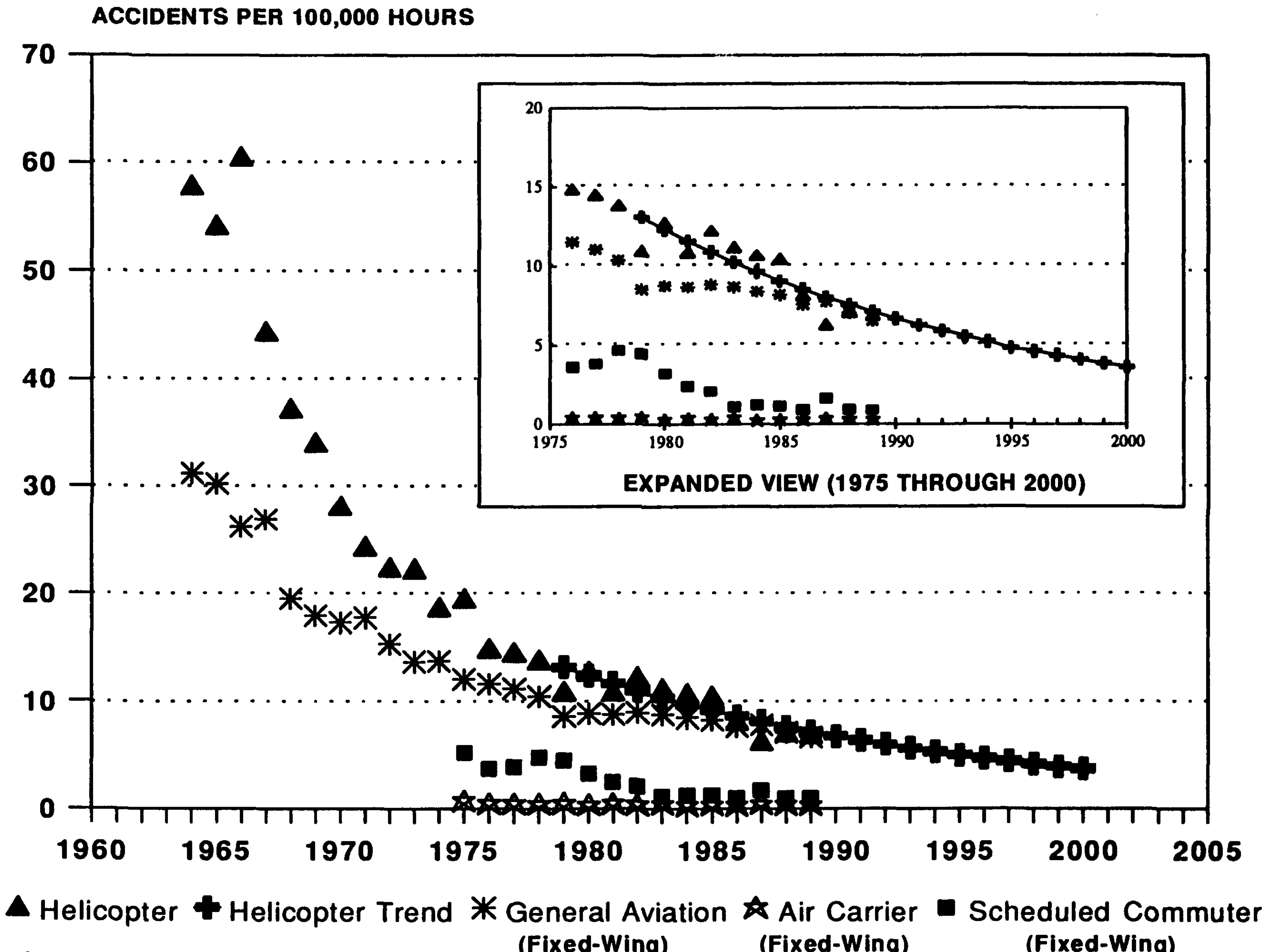
NOTE: Offshore Part 135 operations as reported by HSAC and Rotor & Wing International have been subtracted from FAA data for the air taxi mission.

FIGURE 14 AIR TAXI/COMMERCIAL FLIGHT HOUR FORECASTS (EXCLUDES OFFSHORE)



NOTE: Offshore Part 135 operations as reported by HSAC and Rotor & Wing International have been subtracted from FAA data for the air taxi mission.

FIGURE 15 AIR TAXI/COMMERCIAL FLEET FORECASTS (EXCLUDES OFFSHORE)



Source: Reference 25.

FIGURE 16 TARGET LEVEL OF SAFETY, HELICOPTER ACCIDENT RATES

3.3 ROTORCRAFT MISSIONS

One of the first requirements of this project was to identify the various missions that rotorcraft perform. In total, 33 missions (references 11 and 12) were identified and are presented in table 1. An overview of each of these missions is presented in the first interim report. Those missions thought most likely to derive significant benefits from improved low altitude CNS service were then selected for detailed analysis. The selection criteria used to identify the potential benefits were: number of operations, increased safety, increased efficiency, time criticality, and the value of a trip (reference 5).

TABLE 1
LIST OF HELICOPTER MISSIONS

Aerial Advertising	Law Enforcement
Agriculture	Logging
Air Carrier	Offshore
Air Taxi/Commercial	Photography/Movies
Bank Paper Transport	Pollution Detection
Business	Power/Pipeline Patrol
Corporate/Executive	Private/Personal Use
Construction	Research
Exploration	Sales
External Load	Scheduled Commuter
Electronic News Gathering	Search and Rescue
Emergency Medical Service	Sightseeing
Fire Control Support	Skiing/Hiking
Fish Spotting	Survey
Forestry	Small Package Delivery
Herding	Ranching
	Training

Based on these criteria, seven missions were concluded to have a need for improved CNS and air traffic control procedures. These seven missions are:

- Air Taxi/Commercial
- Business
- Corporate/Executive
- Emergency Medical Service
- Offshore
- Scheduled Commuter
- Search and Rescue

While initially included, the search and rescue mission (SAR) was later excluded. At the beginning of the analysis, it was reasoned that the value of a successful SAR mission could be a life saved (for FAA benefit/cost purposes, a life is currently valued at $1.5 million), (reference 8). It was thought that any improvements to the NAS that could increase SAR mission success might be justifiable in benefit/cost terms. Further investigation, however, showed that the SAR mission is generally performed VFR outside of controlled airspace,

and in areas with low air traffic congestion. The mission also typically requires visual work, which minimizes the usefulness of flying IFR. Based on these considerations and discussions with operators, the SAR mission was excluded from the analysis.

For the six remaining missions, variable operating costs and disruption costs were calculated. These values are presented in table 2. Variable operating costs are defined as those that directly change in proportion to aircraft activity or usage, such as fuel, oil and maintenance. Flight crew expenses are included as variable operating costs only for the air carrier, air commuter, and air taxi missions (reference 8). Flight disruption costs for each of these missions are developed using the FAA's general aviation flight disruption equation (reference 13). Flight disruption costs were developed for each mission through application of this equation. A more thorough explanation of the development of the variable operating and disruption costs is presented in reference 14.

All avionics equipage rates are defined in the second interim report (reference 14) for each mission category. It is not possible to set or assume a consistent equipage rate for all the missions because actual equipage rates vary widely from mission to mission. However, some trends in the helicopter industry are emerging. First, all multiengined turbine helicopters are IFR certifiable. Discussions with manufacturers confirm that almost 100 percent of multiengined turbine helicopters delivered are IFR certified. Since most of the new EMS helicopters are multiengined turbine, it follows that in the near future this mission will be nearly 100 percent IFR equipped. The same will be true for the commuter mission which will require multiengined rotorcraft for safety and IFR capability for reliable scheduled service. The business, executive, air taxi, and offshore missions will probably adopt IFR capability more slowly. These missions will be more dependent on having an infrastructure of IFR heliports in place to justify the cost of the additional avionics and aircraft systems. However, all multiengined rotorcraft will most probably all be IFR equipped. Only smaller piston engine and single-engine turbine helicopters will continue to operate under VFR for 100 percent of their operations.

3.3.1 Air Taxi/Commercial

For this study, the air taxi/commercial mission includes all Title 14 Code of Federal Regulations (CFR) Part 135 operations except those performing emergency medical services, offshore, and scheduled commuter operations. Because of their differing mission requirements, these three 14 CFR Part 135 operations are considered in separate categories. The air taxi/commercial missions considered here include: on-demand passenger or cargo transport, photography, sightseeing, geologic and seismic survey, powerline and pipeline patrol, construction, bank paper transport, and traffic reporting. In addition, some commercial operators have contracts with government agencies that allow them to be called in cases of emergency, such as fighting forest fires, floods, and disaster relief. Of the operations

TABLE 2 ROTORCRAFT ECONOMIC COSTS (1990 DOLLARS)

A	B	C	D	E	F	G
MISSION	VARIABLE OPERATING COSTS PER HOUR	AVERAGE NUMBER OF PASSENGER/ OCCUPANTS	VALUE OF OCCUPANTS TIME	DIVERTED PASSENGER HANDLING EXPENSE	TOTAL DELAY COSTS PER HOUR	TOTAL COST PER DISRUPTION
EMS	$155.30	3.50	$125.55	$78.06	$594.73	$804.71
OFFSHORE	155.30	4.50	83.70	78.06	531.95	702.83
AIR TAXI	217.80	3.30	87.43	78.06	506.32	559.32
BUSINESS	155.30	2.00	83.70	78.06	322.70	331.35
CORP/EXEC	155.30	3.30	83.70	78.06	431.51	524.52
COMMUTER	217.80	4.80	83.70	78.06	619.56	761.15

Source: Reference 14.

considered for this category, photography and sightseeing represent the majority of the hours flown.

The air taxi/commercial mission is performed throughout the United States. However, most of the flights occur in several geographic areas that encompass major metropolitan centers. The Northeast (New York City, Boston, Philadelphia, and Washington, DC) includes a large percentage of the air taxi/commercial operators. Southern Florida, Seattle, San Francisco, and Los Angeles support the bulk of the remaining air taxi/commercial business. Air taxi operations employ approximately 1,600 helicopters and fly nearly one million hours per year.

Both single-engine and twin-engine helicopters are used to support the mission. However, the majority of hours are accomplished in single-engine turbine aircraft. Many of the aircraft used for this mission are not IFR-certificated, and more than 90 percent of these flights are flown under VFR.

Unfavorable weather conditions represent the biggest constraint to the air taxi/commercial mission. Many air taxi IFR operations are restricted during the winter months, particularly in the Northeast, by icing conditions. None of the helicopters used for this mission are certificated for flight into known icing conditions. Consequently, operations are disrupted during icing conditions.

Another constraint arises from air taxi flights near major city centers. These aircraft must mix with the high density traffic that is common near major population centers and comply with ATC procedures for operating within this congested airspace. Published helicopter route charts have helped to organize the traffic flow and reduce delays in areas such as New York City, Boston, Washington, D.C., Chicago, and Los Angeles.

3.3.2 Business

The business mission primarily caters to transporting business owners between business locations and local airports. By definition, a business mission occurs when the pilot of the aircraft is also the owner of the business. Most business operations are performed under 14 CFR Part 91, although some missions are flown using chartered aircraft under 14 CFR Part 135. Other mission support uses include aerial inspection of property, buildings, job sites, and transportation of clients.

Flights in the business category occur throughout the United States. However, several areas experience a higher number of business operations compared to the rest of the country. The Northeast, the Northwest, Southern California, and Florida represent areas that experience the largest percentages of business flights. Nationwide, approximately 400 helicopters flying nearly 75 thousand hours per year support this mission.

Business missions are typically conducted with single-engine piston or turbine aircraft. Popular models include the Robin R-22, Enstrom F-28, Schweizer/Hughes 300, Bell 206, and Aerospatiale AStar. Most business flights are of short duration and many are flown repeatedly to the same destinations to support the business.

These aircraft are typically not IFR-certificated nor are the pilots IFR-rated. Consequently, instrument meteorological conditions (IMC) often disrupt this mission and business flights are mostly limited to flying under VFR. As with other missions, flying in and around major city centers can present problems.

3.3.3 Corporate/Executive

The corporate/executive mission consists of the transport of company executives, personnel, and clients in corporate-owned aircraft. Similar to the business mission in purpose, most corporate/executive missions are flown under 14 CFR Part 91. However, they differ from the business mission in that the corporations hire pilots, usually full-time, to fly these missions in corporate aircraft. The primary goal of the corporate/executive mission is to provide an alternative to ground transportation that can significantly reduce the amount of time spent traveling by personnel, especially top executives. In addition, this mission provides an alternative to travel by commercial means. This is particularly useful for trips that are less than 300 miles, where much of the travel time can be spent traveling to and waiting at airports.

Corporate/executive flights occur throughout the United States. The largest percentage of flights in this category occur in the Northeast. Single-engine turbine and twin-engine turbine helicopters primarily perform this mission. Most of the large twin-engine turbine rotorcraft supporting the corporate/executive mission are flown in the Northeast and to a lesser extent in Southern California. In the Northeast, many of the rotorcraft are IFR-certificated and the flight crews are IFR-qualified. Nearly 800 helicopters support this mission and flew a total of 250,000 hours in 1989. The number of helicopters and flight hours are forecast to double by the year 2007.

One significant constraint to this mission is a lack of heliports, especially public heliports in city centers. The limited number of heliports restrict the corporate/executive operation from landing at or near desired locations in many metropolitan areas. Another constraint to the mission is the inability to fly in icing conditions. This is of primary concern in the Northeast during the winter months. During IMC, helicopters are forced to fly at higher altitudes in the ATC system. Icing conditions often occur at these higher altitudes, and since none of the helicopters are certified for icing conditions, these flights must be canceled.

Delays due to high aircraft activity levels in airspace around cities and high activity airports also constrain this mission. For example,

during peak traffic hours at New York City airports, rotorcraft pilots report delays of 10 to 30 minutes. Rotorcraft pilots stressed that helicopters have unique flying capabilities, and therefore ATC should take advantage of these capabilities to expedite helicopter traffic.

3.3.4 Emergency Medical Service

The EMS mission's primary purpose is to provide for the rapid transportation of critically ill or injured individuals. This service, unique from the other missions, is extremely valuable to the community. Most EMS programs contract helicopters and crews from commercial operators to support their hospital needs. Therefore, most EMS operations are performed under 14 CFR Part 135. In addition, public services that use helicopters, such as state police, local police, and local firefighters, may perform EMS operations. These operations are typically performed under 14 CFR Part 91.

The EMS mission fulfills two primary roles. The first and most widely known is accident scene pickup, although this service accounts for only about 20 percent of the EMS missions in recent years. The primary role of the EMS helicopter has been the inter-hospital transfer of patients and medical supplies, which accounts for the other 80 percent.

EMS missions are flown throughout the United States in both urban and rural areas. The number of EMS helicopters and their hours flown have significantly increased during the 1980's. The fleet size is forecast to double by the year 2007, employing 450 helicopters, and the number of hours flown will increase to more than 250,000 (reference 14).

Over 93 percent of the continental United States is serviced by an EMS program (reference 28). The mission is particularly beneficial in rural locations because of the capability to transport patients quickly to distant hospitals. Most missions are flown in visual meteorological conditions (VMC). However, many of the helicopters are IFR-certificated and the majority of pilots are IFR-qualified and current. Although few EMS operators currently accept IFR missions, they like to have IFR capability in case a mission should encounter IMC while en route. Most EMS helicopters have twin-turbine engines, with the remainder primarily having a single-turbine engine.

Currently, a major constraint to the mission is the lack of available weather information. This is particularly true in rural areas where weather observations are often lacking. Access to weather information is most critical in supporting night missions. The chances of inadvertently flying into IMC at night are much greater than during the day.

Unlike other rotorcraft missions, EMS pilots reported few delays when operating in controlled airspace. In most cases, air traffic controllers are well aware of local EMS programs and give EMS helicopters priority handling. In addition, incorporation of the term

"lifeguard" mandates priority handling if the patient needs immediate care.

3.3.5 Offshore

The offshore mission supports the oil industry by transporting personnel and equipment to and between offshore oil and gas rigs. Offshore helicopters also provide EMS services to personnel on the rigs if necessary. Approximately 80 percent of the offshore helicopters are supplied through commercial operators and are operated under 14 CFR Part 135. The remaining 20 percent of the fleet are owned by the oil companies themselves and operate under 14 CFR Part 91.

Offshore missions are flown primarily in the Gulf of Mexico and the North Slope of Alaska. To a lesser extent, rotorcraft also support oil rigs off the coast of California. Rotorcraft operators in the Gulf of Mexico primarily support oil rigs located south of Galveston, Texas and New Orleans, Louisiana. Some of the rigs are located as far as 150 miles offshore; however, the majority are located within 80 miles of land. In the future, rigs are expected to be located as far as 200 miles offshore. Most oil rigs in the North Slope are within 20 miles of the shore line.

The majority of offshore missions are flown under VFR. Most of the pilots are IFR-qualified but many do not maintain their currency. Helicopters that support the mission range from the Bell 47 to the Boeing 234. Single-engine turbine helicopters currently comprise about 60 percent of the fleet. The number of annual operations for the mission is highly dependent upon the fortunes of the petroleum industry. In 1989, the mission employed more than 600 helicopters flying nearly 600,000 hours. The number of helicopters used over the next 2 decades is forecast to almost double (1,100 aircraft), while the number of flight hours will increase by about 80 percent to 830,000.

Inadequate surveillance in the Gulf of Mexico is the primary constraint on the mission. Under VMC, radar could increase rotorcraft safety levels by enabling ATC to provide flight following. A number of the operators track their own aircraft for safety and business purposes using LORAN-C offshore flight following (LOFF) or a similar system.

The greatest reason for enhancing surveillance in the Gulf of Mexico is to provide better separation of IFR rotorcraft operating over water. Without radar coverage, air traffic controllers are forced to use non-radar separation standards. This limits the number of flights that can occur during IMC. IFR routes in the Gulf run primarily in a north-south direction. As a result, east-west IFR traffic flow is severely limited.

3.3.6 Scheduled Commuter

Scheduled commuter rotorcraft operations provide a service to the community by offering an alternative means of air transport in and among major metropolitan centers. The primary benefit of this service is that it avoids the delays normally associated with commuting inside congested areas. Scheduled commuters primarily transport business passengers between international airports and city centers. These operations follow a regular schedule and are considered "air carriers." Current operations are conducted under 14 CFR Part 135 (SFAR 38-2 has waived the application of 14 CFR Part 127-Certification and Operation of Scheduled Air Carriers with Helicopters.)

Scheduled commuter operations occur in only three metropolitan areas in the United States. These areas include Boston, New York, and Los Angeles. Operations are conducted along routes that have been coordinated with local ATC personnel. The Boston operations are provided by Digital Equipment Corporation (DEC) for company personnel only and are conducted under 14 CFR Part 91. The other two commuter operations are Trump Airlines in New York City and LA Helicopters in Los Angeles. Because of its mission characteristics, DEC's operations are categorized as a scheduled commuter mission for this report. All scheduled commuter operations, except DEC, are conducted under VFR or SVFR. One DEC helicopter is IFR-certificated and flies in IMC when the need arises. Scheduled commuter flights are typically of short duration and are usually conducted below 2,000 feet AGL.

More than any other mission, scheduled commuter services are highly dependent on the country's economic well-being. The mission operates on a small margin of profit, and during economic downturns revenue is very much affected. The number of helicopters used for scheduled commuters and the annual number of flight hours flown have fluctuated dramatically in recent years. Historically, rotorcraft scheduled commuter operations have been erratic; therefore, projecting future growth is unreliable. However, extrapolating trends from historical data would indicate that by 2007, approximately 40 rotorcraft will support the scheduled commuter mission with more than 35,000 hours being flown annually.

The largest constraint to the mission is weather. Since the majority of aircraft are not IFR-certificated, missions are conducted primarily under VFR or SVFR. If operations cannot be flown because of weather, passengers have the alternative of using ground transportation. However, passengers could rapidly become disenchanted with the mission if flights are periodically canceled.

Another restraint to the mission involves delays encountered at airports because of congestion. Delays of 5 to 20 minutes are common during peak traffic periods. Although these delays are common for all aircraft, mission competitiveness requires maintaining a strict schedule and alternative procedures using the helicopter's unique capabilities could virtually eliminate delays.

3.4 SITE SELECTION

After identifying the rotorcraft missions to be analyzed, 50 sites were identified that could most likely benefit from improvements to the NAS. The selection criteria considered both the number of helicopters based in the county and the percentage of time the weather was below a 500 feet ceiling or 1 mile visibility. These weather conditions were chosen, because they represent typical existing rotorcraft weather minimums. Where appropriate, the formula was adjusted to account for such factors as population, annual number of EMS missions, mountainous terrain, and the elimination of helicopters not performing the selected missions. Figures 17 and 18 depict site locations and table 3 provides the number and types of missions at the sites.

The frequency of IMC at each of the 50 sites is presented in table 4. The sites are listed alphabetically by state and county.

Column three gives the percentage of time the weather is between 1,000 foot ceiling and 2 miles visibility and 400 foot ceiling and 3/4 mile visibility, and column four give the percentage of time the weather is between 800 foot ceiling and 1 mile visibility and 466 foot ceiling and 3/4 mile visibility.

These 50 sites became the focus of the analysis. Operational issues were discussed with the local operators, CNS coverages assessed, and existing and future rotorcraft operational problems identified. From focusing on these issues and geographic locations, conclusions regarding current and future operational issues were developed.

3.5 OPERATIONAL CONSTRAINTS AND ISSUES

A correct understanding of future rotorcraft operational requirements is essential to this investigation and is presented in the following sections. These requirements are identified by projecting existing requirements, as described by rotorcraft operators, into the planned NAS in the year 2000. The year 2000 was chosen, because it marks the end of the CIP's midterm improvement period.

3.5.1 VFR Flight

The majority (99 percent of the flight hours; reference 26) of existing rotorcraft flights in the United States are performed VFR. VFR flight, compared to IFR flight, enables rotorcraft to fly with greater freedom and efficiency. The FARs' contain several important exceptions that increase the rotorcraft's capability to operate unconstrained while VFR, particularly in conditions of low ceilings or poor visibilities.

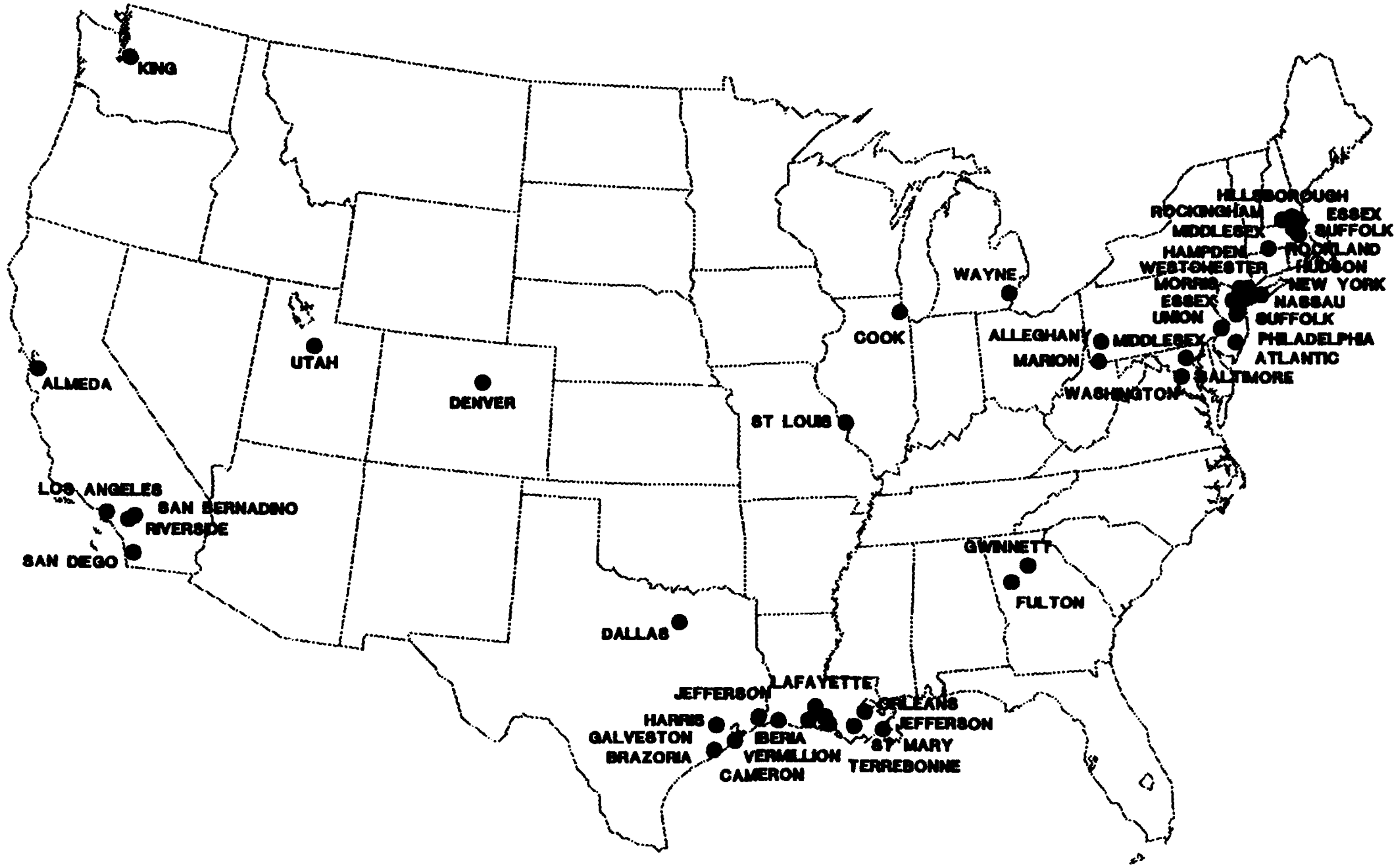


FIGURE 17 SELECTED COUNTY SITES - CONUS

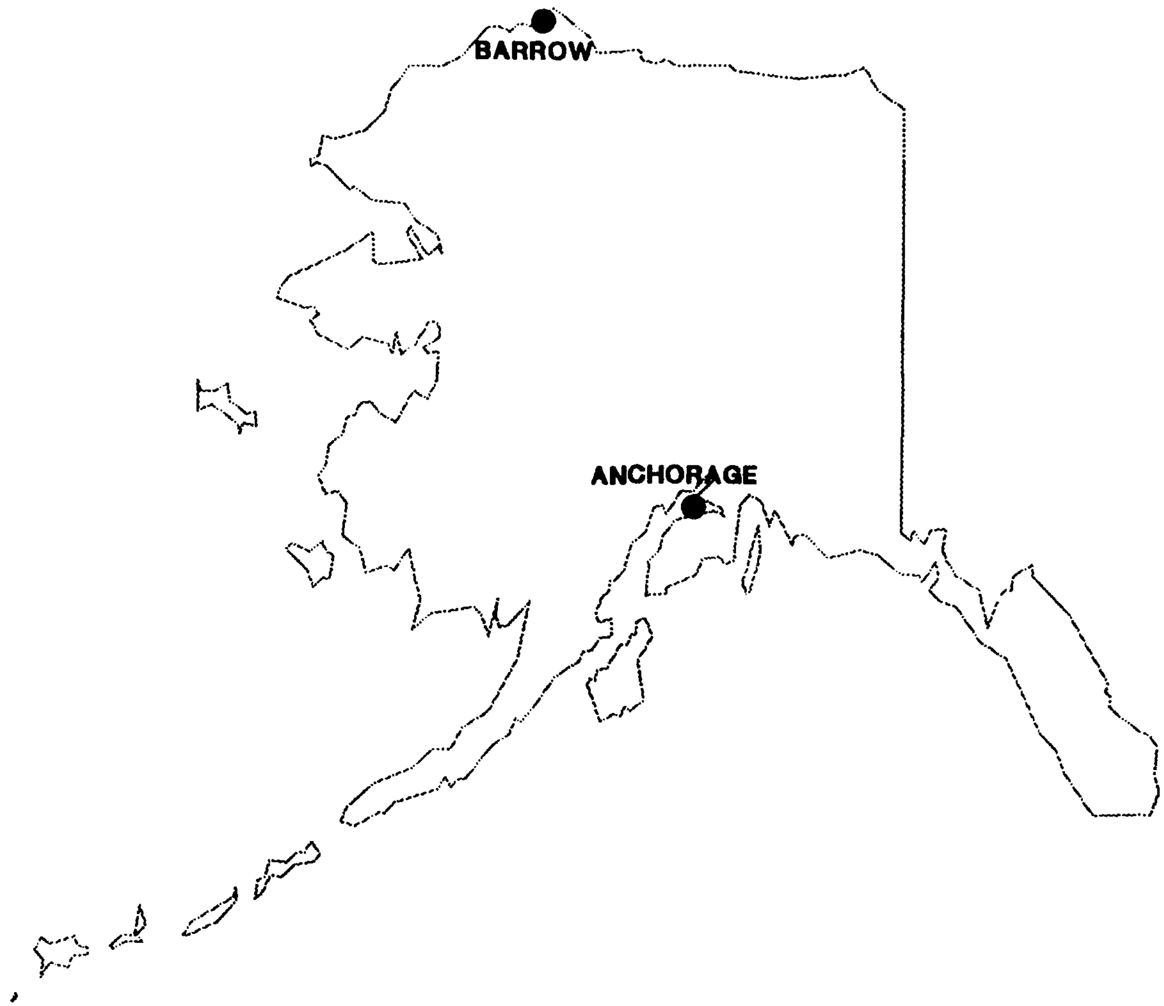


FIGURE 18 SELECTED SITES - ALASKA

TABLE 3
COUNTIES SELECTED FOR LOW ALTITUDE IFR BENEFITS STUDY

RANK	ST	COUNTY	EMS	SAR	OFF-SHORE	CORP/BUSIN	COM-MUTER	AIR TAXI	BASED HELOS	COMMENTS
252	TX	BRAZORIA	Y	N	Y	N	N	Y	74	HIGH INDEX/MULTI MIS
246	CA	LOS ANGELES	Y	Y	N	N	Y	Y	158	HIGH INDEX/MULTI MIS
208	LA	VERMILION	N	N	Y	N	N	N	56	HIGH INDEX
206	CA	SAN BERNARDINO	Y	N	N	Y	N	Y	69	HIGH INDEX/MULTI MIS
168	LA	ORLEANS	Y	Y	Y	Y	N	Y	64	HIGH INDEX/MULTI MIS
164	TX	JEFFERSON	Y	N	Y	Y	N	Y	47	HIGH INDEX/MULTI MIS
155	CA	ALAMEDA	Y	N	N	Y	N	Y	47	HIGH INDEX/MULTI MIS
149	LA	CAMERON	N	N	Y	N	N	N	38	HIGH INDEX
117	LA	JEFFERSON	Y	N	Y	N	N	N	37	HIGH INDEX
107	GA	GWINNETT	Y	N	N	N	N	Y	23	HI INDEX/NEAR ATLANTA
98	NJ	HUDSON	Y	N	N	Y	N	N	22	MID INDEX/NYC GROUP
89	LA	IBERIA	N	N	Y	N	N	N	94	MID INDEX/GULF GROUP
88	AK	BARROW	Y	Y	Y	N	N	N	12	MID INDEX/MULTI MIS
86	NY	SUFFOLK	Y	N	N	Y	Y	Y	26	MID/MULTI MIS/NYC GROUP
83	AK	ANCHORAGE	Y	N	Y	N	N	Y	55	MID INDEX/MULTI MIS
81	NJ	UNION	Y	N	N	Y	N	N	18	MID INDEX/NYC GROUP
77	CA	RIVERSIDE	Y	N	N	Y	N	Y	48	MID/MULTI/SCAL GROUP
77	MA	ESSEX	Y	N	N	N	N	Y	10	MID INDEX/BOSTON
68	NH	HILLSBOROUGH	N	N	N	Y	N	Y	16	MID INDEX/BOSTON
64	NY	NEW YORK	Y	Y	N	Y	Y	Y	13	MID INDEX/MULTI MIS/NYC
63	NH	ROCKINGHAM	N	N	N	Y	N	Y	9	MID INDEX/BOSTON
62	MA	MIDDLESEX	N	N	N	Y	N	Y	16	MID INDEX/BOSTON
61	MI	WAYNE	Y	N	N	N	N	N	37	MID INDEX/DETROIT
59	LA	ST MARY	N	N	Y	N	N	N	94	MID INDEX/GULF GROUP
59	NY	WESTCHESTER	Y	N	N	Y	N	N	16	MID INDEX/NYC GROUP
57	CA	SAN DIEGO	Y	Y	N	Y	N	N	83	MID/MULTI/SCAL GROUP
57	NY	ROCKLAND	N	N	N	Y	N	N	12	MID INDEX/NYC GROUP
55	UT	UTAH	Y	N	N	N	N	Y	100	HIGH INDEX/MOUNTAINS
54	MA	HAMPDEN	Y	N	N	Y	N	N	7	MID INDEX/BOSTON
53	LA	LAFAYETTE	Y	N	Y	Y	N	Y	28	MID/MULTI/GULF GROUP
47	MA	SUFFOLK	Y	N	N	N	N	N	6	LOW INDEX/BOSTON
45	NJ	ATLANTIC	N	N	N	N	Y	Y	25	LOW INDEX/COMMUTER
41	LA	TERREBONNE	Y	N	Y	N	N	N	62	MID/OFFS&EMS/GULF GROUP
41	TX	GALVESTON	Y	N	Y	N	N	N	51	LOW INDEX/GULF GROUP
41	WA	KING	Y	N	N	Y	N	Y	45	LOW INDEX/SEATTLE
35	GA	FULTON	Y	N	N	Y	N	Y	31	LOW INDEX/ATLANTA
34	PA	PHILADELPHIA	Y	N	N	N	N	Y	27	LOW INDEX/PHILADELPHIA
34	PA	ALLEGHENY	Y	N	N	Y	N	Y	18	LOW INDEX/PITTSBURGH
32	TX	HARRIS	Y	N	Y	Y	N	Y	170	LOW INDEX/HOUSTON
29	NY	NASSAU	N	Y	N	Y	N	Y	30	LOW INDEX/NYC GROUP
24	NJ	MORRIS	N	N	N	Y	N	N	23	LOW INDEX/NYC GROUP
22	NJ	MIDDLESEX	Y	N	N	N	Y	N	5	COMMUTER BASE/NYC GROUP
21	IL	COOK	N	N	N	Y	N	Y	44	LOW INDEX/CHICAGO
20	TX	DALLAS	Y	N	N	Y	N	N	60	LOW INDEX/DALLAS
16	IN	MARION	Y	N	N	Y	N	Y	34	LOW INDEX/INDIANAPOLIS
13	MD	BALTIMORE	Y	N	N	Y	N	Y	37	LOW INDEX/WASH GROUP
11	MO	ST LOUIS	Y	N	N	Y	N	Y	41	LOW INDEX/ST LOUIS
10	DC	WASHINGTON	Y	N	N	N	N	N	3	LOW INDEX/WASH DC
10	NJ	ESSEX	N	N	N	Y	N	N	7	LOW INDEX/NYC
6	CO	DENVER	Y	N	N	Y	N	N	7	LOW INDEX/DENVER

Y = Mission Performed N = Mission not Verified

TABLE 4
PERCENT IMC WEATHER FOR SELECTED COUNTIES

COUNTY	STATE	CEILING: >466'&<1000' VISIBILITY: >.75mi&<2mi	>466'&<800' >.75mi&<1mi
ANCHORAGE	AK	2.7	1.4
BARROW	AK	18.2	9.7
ALMEDA	CA	6.9	3.6
LOS ANGELES	CA	10.6	5.6
RIVERSIDE	CA	11.0	5.8
SAN BERNADINO	CA	11.0	5.8
SAN DIEGO	CA	6.7	3.5
DENVER	CO	2.8	1.5
WASHINGTON	DC	5.4	2.9
FULTON	GA	6.3	3.4
GWINNETT	GA	6.3	3.4
COOK	IL	7.4	3.9
MARION	IN	7.6	4.0
CAMERON	LA	6.5	3.4
IBERIA	LA	6.2	3.3
JEFFERSON	LA	4.8	2.5
LAFAYETTE	LA	6.2	3.3
ORLEANS	LA	4.8	2.5
ST MARY	LA	6.2	3.3
TERREBONNE	LA	4.8	2.5
VERMILLION	LA	6.2	3.3
ESSEX	MA	5.8	3.3
HAMPDEN	MA	5.6	3.0
MIDDLESEX	MA	5.8	3.3
SUFFOLK	MA	7.1	3.7
BALTIMORE	MD	5.6	3.0
WAYNE	MI	7.3	3.9
ST LOUIS	MO	5.9	3.1
HILLSBOROUGH	NH	6.3	3.4
ROCKINGHAM	NH	5.8	3.3
ATLANTIC	NJ	6.7	3.5
ESSEX	NJ	8.1	4.3
HUDSON	NJ	7.6	4.1
MIDDLESEX	N	7.5	3.9
MORRIS	NJ	8.1	4.3
UNION	NJ	6.8	3.6
NASSAU	NY	5.8	3.3
NEW YORK	NY	7.6	4.1
ROCKLAND	NY	7.5	3.9
SUFFOLK	NY	6.9	3.6
WESTCHESTER	NY	7.6	4.1
ALLEGHANY	PA	7.6	4.0
PHILADELPHIA	PA	6.5	3.5
BRAZORIA	TX	6.4	3.3
DALLAS	TX	4.3	2.3
GALVESTON	TX	6.4	3.3
HARRIS	TX	6.4	3.3
JEFFERSON	TX	6.5	3.4
UTAH	UT	2.4	1.3
KING	WA	6.5	3.4
NATIONAL AVERAGE		6.0	3.0

Equally as important as the FARs in enabling VFR rotorcraft to fly in lower ceilings and visibilities than fixed-wing aircraft are the exceptions made for rotorcraft flying under SVFR*. FAR 91.157 basically requires that SVFR rotorcraft remain clear of clouds and the pilot maintain visual contact with the ground. Air traffic control procedures are equally flexible and permit reduced aircraft separation. Some air traffic facilities will enforce an additional restriction and discontinue SVFR operations in their control zones when ceilings are less than 500 feet or visibilities are less than 1 mile (reference 15). This restriction, however, has minimal impact since rotorcraft are rarely flown in lower ceilings or visibilities.

The eased VFR and SVFR requirements that apply to rotorcraft increase the capacity of the NAS and reduce overall delays. No evidence would suggest that any of these exceptions will be eliminated. Rotorcraft will therefore continue to fly VFR with lower weather minimums and greater opera .onal flexibility than their fixed-wing counterparts.

Rotorcraft pilots flying VFR nonetheless encounter limitations in the NAS that restrict their freedom. For the en route phase, pilots have few criticisms. In other phases, however, they complain of the limited routes over many congested areas, communications frequency congestion, and the lack of weather reporting in noncongested areas.

Rotorcraft pilots are encumbered when flying over numerous congested areas throughout the country. In most major urban centers, pilots are limited to only a few routes on which to fly through an area. These routes have been specified in letters of agreement between operators and the appropriate air traffic control facility. These letters of agreement are cumbersome and time-consuming to develop. They require that both operators and air traffic controllers give each request individual attention, and they do little to benefit itinerant rotorcraft flights.

The Helicopter Route Chart Program (reference 16) provides a better alternative for many cities. These charts have already been developed for New York City, Baltimore-Washington, Chicago, Boston, and Los Angeles. Rotorcraft pilots and air traffic controllers from these areas generally praise their usefulness and convenience (reference 15).

In January 1990, the FAA issued additional instruction on Helicopter Route Charts for inclusion in the Facilities Operation and Administration Handbook 7210.3I. These instructions establish a systematic process for future chart development and contain procedures for the modification of existing charts. Discussions with operators indicate this program, when properly implemented, addresses many of their operational needs.

*Note: SVFR applies only to control zones and only when the ceiling is less that 1,000 feet or the visibility is less than 3 miles.

Pilots flying VFR also comment that the availability of weather information is inadequate in remote areas and at night. Accurate up-to-date weather information is particularly important for rotorcraft operators as they frequently fly during low ceilings and visibilities, are unable to fly IFR, and fly at low altitudes over many sparsely populated areas.

The FAA has acknowledged this need and is in the process of significantly upgrading the weather reporting system (reference 1). The primary upgrade will include more than 1,000 automated weather observing systems (AWOS) at airports and heliports across the United States. AWOS will obtain aviation critical weather data through automated sensors. It will then disseminate the data to pilots via a computer-synthesized voice.

Other systems will be implemented to improve rotorcraft pilots' access to weather information. The Flight Service Automation System (FSAS) will automate many flight service functions. The result will be a greater capacity to handle projected increases in demand for flight services. The aeronautical data link (ADL) will enable Mode-S to provide weather information. Also, installation of the central weather processor (CWP) will improve the meteorologists' ability to analyze rapidly changing weather conditions. All four of these systems are planned to be fully implemented by the end of 1996. This expanded and improved capability will satisfy many rotorcraft user needs that have previously gone unmet.

VFR operational constraints in terminal areas most frequently occur at high activity airports. The primary constraints are inadequate voice access to controllers due to frequency congestion and delays due to ATC workload. During peak hours at several high activity airports, ATC positions have been dedicated to rotorcraft service. Rotorcraft pilots state "rotorcraft controllers" in these areas satisfy rotorcraft operational needs.

Frequency congestion and availability was also noted as a problem at low-activity facilities. Pilots complain that the common traffic advisory frequency is frequently too congested to be useful. As a result, some pilots rely exclusively on visual separation at uncontrolled facilities.

At airports where ATC does not normally handle rotorcraft, rotorcraft pilots often comment about air traffic controllers' lack of experience with rotorcraft. Delays resulting from some controllers' inexperience is only a minor problem, since their airspace is seldom used by rotorcraft.

On a national level, CNS coverages were not considered to be a problem among rotorcraft pilots flying VFR. Minimal communications and surveillance coverages are needed while in the en route phase and the existing navigation signals (VHF omnidirectional range (VOR)/distance measuring equipment (DME) and especially LORAN-C) provide satisfactory

coverage. Entry into terminal airspace usually requires communications, and entry into high-activity control zones while SVFR often requires surveillance as well. CNS systems are properly located and the typical rotorcraft entry routes into these terminal airspaces alleviate problems from building or terrain masking.

Lack of surveillance continues to be an issue in the Gulf of Mexico. Hundreds of offshore VFR helicopter flights are performed daily that are beyond surveillance coverage. Improved surveillance could provide Houston Center with a flight-following capability contributing to additional flight safety. Historically, an average of 2.1 VFR helicopters crash in the waters off the coast of Louisiana and Texas each year (reference 4). Flight-following service provided by Houston Center would result in quicker response times to these accidents.

3.5.2 IFR Flight

Rotorcraft flying IFR face more constraints than those flying VFR. Most en route restrictions are geographically specific, while terminal area constraints are similar regardless of the operating region.

3.5.2.1 IFR En Route Flight

In most regions of the country, rotorcraft pilots experience few operational constraints while flying IFR en route. VOR Federal airways provide numerous altitudes and alternative routes and are therefore adequate to serve rotorcraft and fixed-wing aircraft. Also important is the fact that the rotorcraft's flight characteristics become nearly indistinguishable from those of fixed-wing aircraft that operate in the low altitude airway structure. In other words, IFR rotorcraft in the low altitude, en route environment operate at speeds and altitudes that are characteristic of the fixed-wing aircraft.

The expansion of tower en route control (TEC) also has enhanced communications and surveillance capabilities in controlled airspace near major terminal areas*. TEC uses the more numerous terminal communications and surveillance systems rather than en route systems. The result is superior low altitude coverage in areas where TEC is applied.

Two regions where IFR rotorcraft are encountering en route problems are in the Northeast and in the Gulf of Mexico. These regions also contain a high percentage of IFR-certificated rotorcraft. The Northeastern United States is of particular interest, since the

*Note: TEC, as specified in FAA Order 7110.91, enables the Air Route Traffic Control Center (ARTCC) to delegate a specified amount of airspace to approach control for air traffic control service. Delegating a number of adjacent pieces of airspace to the appropriate approach control enables the approach controls to provide en route service to low altitude aircraft.

airspace has high fixed-wing and rotary-wing activity levels and frequently has IMC. The Northeast therefore provides an excellent glimpse of some of the potential future problems rotorcraft will experience in other areas.

The cause of rotorcraft en route problems in the Northeast arises from the high incidence of icing conditions at lower altitudes during the colder months. Low altitude icing conditions result in rotorcraft needing to fly as low as possible to remain under the freezing level and avoid icing. Preferred low altitude IFR routes are frequently unavailable due to gaps in surveillance coverage, congested low altitude airways (during icing), and the NAS East Coast Plan**.

Surveillance coverage in the Northeast recently improved. Surveillance is now provided down to the minimum en route altitudes (MEAs) of VOR Federal airways supporting north-south flights in the Northeast. The gaps in surveillance coverage to the north of Philadelphia have recently been filled with the replacement of the previous airport surveillance radar with a superior radar, the ASR-9.

This new radar system has also been repositioned, resulting in improved low altitude coverage. Surveillance coverage in the airspace around Rhode Island has also improved recently with the installation of radar at Quonset Point Naval Air Station, RI.

Congestion in the low altitude airways below the freezing level does significantly increase when icing conditions occur as other aircraft also prefer to avoid icing. In the en route environment, this increased congestion still has not been a significant contributor to rotorcraft delays.

The NAS East Coast Plan was developed by the FAA to provide organized traffic flows that ATC could more easily manage. As a result, in highly congested airspace, rotorcraft experience significant rerouting. Rerouting traffic results in more manageable traffic flows through terminal areas, and into and out of highly congested airports. Therefore, the reroutings in this area will be considered a terminal airspace problem.

In the Gulf of Mexico, rotorcraft IFR problems are due to the lack of offshore surveillance and communications coverages. The FAA's Southwest Region has acknowledged this problem and solutions have been proposed; however, no action has been taken at this time.

The lack of radar surveillance in the Gulf of Mexico results in non-radar separation (10 minutes or 20 miles instead of 5 miles) being applied to IFR rotorcraft. The current offshore rotorcraft fleet in

**Note: Aircraft are also frequently rerouted while en route in accordance with the East Coast Plan. This constraint is considered a terminal area problem and is discussed in section 3.6.3.

the Gulf of Mexico consists of more than 115 IFR-certificated rotorcraft (reference 17) and delays are frequent. Air traffic controllers believe if radars were installed in the Gulf of Mexico, these existing delays of 30 to 45 minutes could be virtually eliminated.

To a lesser degree than gaps in surveillance, gaps in communications remain an operational problem in the Gulf of Mexico. Low altitude communications gaps exist between the five remote communications facilities (RCFs) that are located offshore. Delays result during an instrument approach, because large blocks of airspace must be protected until someone from the rig reports the rotorcraft is in sight. On an IFR departure, similar delays can result.

Also of concern to the rotorcraft community is that oil drilling is already planned beyond 200 miles offshore. At 200 miles, rotorcraft would be as much as 80 miles beyond communications coverage at 1,200 feet MSL and 40 miles beyond communications coverage at 10,000 feet. The operational effect that this lack of en route communications will have on rotorcraft operations is unknown at this time.

Rotorcraft pilots operating from Texas and Louisiana coastline heliports also comment that in some areas, communications and surveillance are inadequate for the high number of IFR operations being performed in an area. The Lake Pelleur, LA area provides one example. Six different heliports supporting 57 rotorcraft are located on the shore of Lake Pelleur, yet communications do not exist down to the surface. As a result, a single IFR approach or departure prohibits any other IFR operation from being performed until communications between ATC and the pilot are established. As a consequence, IFR operational delays often result.

While the absence of adequate communications and surveillance continues to be a problem in the Gulf of Mexico, the development of innovative procedures is noteworthy. Procedures such as offshore standard approach procedures (OSAP) and airborne radar approaches (ARA) are unique to this area and have satisfied many rotorcraft operational needs. Discussions with both rotorcraft pilots and air traffic controllers in this area suggest that these two groups work very closely toward the common goal of improving rotorcraft flight.

In other areas of the country, minimal IFR rotorcraft operational constraints exist while en route. In general, the VOR Federal airways remain uncongested and serve their purpose. Several factors contribute to this compatibility between IFR rotorcraft and the existing route structure. Rotorcraft en route flight characteristics are similar to those of fixed-wing aircraft; IFR altitudes up to 10,000 feet are acceptable for rotorcraft use; and finally, CNS coverages adequately support the area's activity levels.

3.5.2.2 IFR Flight Terminal Area

While en route constraints are geographic in nature, terminal constraints are similar throughout the country. These constraints can be categorized by high, medium, or low aircraft operation levels.

At high activity airports, several factors cause rotorcraft to experience delays. The first is excessive rerouting that in some cases may commence as far as 100 miles from the destination. For example, helicopters that routinely fly IFR from Massachusetts or Connecticut to New York's LaGuardia Airport are rerouted in the vicinity of Connecticut through eastern Long Island before being allowed to proceed westbound toward New York City. This increases flight time by 38 percent, 55 minutes compared to a direct flight of 40 minutes. Secondly, when approaching the airport, the high level of congestion may cause additional delays and rerouting. (These close-in delays, the result of airspace congestion, also affect fixed-wing aircraft.) Although the Air Traffic Control Handbook, FAA Order 7110.65, instructs controllers to provide service on a "fist come, first served" basis, most controllers admit that they often delay rotorcraft rather than faster aircraft carrying more passengers (reference 18).

Similar delays occur on IFR departure, since rotorcraft must be integrated into the airport's departure pattern. Delays on departure are most notable on the ground as rotorcraft pilots wait for departure clearances. Once airborne, delays are not as common.

Standard instrument departures (SIDs), standard terminal arrival routes (STARs), and point-in-space instrument approaches could be developed that would effectively reduce or eliminate many terminal delays. Such procedures could effectively separate rotorcraft from fixed-wing traffic, resulting in less congestion and delay for both rotary-wing and fixed-wing aircraft.

Rotorcraft operators experience few delays at medium activity airports. Most have adequate CNS and ATC services, and aircraft activity is not sufficiently high to cause sequencing delays greater than a few minutes. No future rotorcraft user needs could be identified for this type of airport that are not being adequately addressed by the FAA.

At low activity airports and heliports, rotorcraft operators will likely experience increased delays and disruptions due to insufficient navigation, communications, and air traffic control services. The foremost problem will likely remain the rotorcraft community's inability to acquire easily implementable, low cost instrument approaches with sufficiently low weather minimums.

The FAA has approved "rotorcraft-only" instrument approaches that have effectively lowered weather minimums. Existing rotorcraft-only nonprecision instrument approaches have average weather minimums of

466 feet and between 1/2 and 3/4 mile visibility (reference 14). These weather minimums are well below other nonprecision instrument approach minimums. However, problems remain with the availability and location of approved navigation aids that define standard instrument approach procedures. Current instrument approaches use VOR/DME or nondirectional beacons (NDBs) to provide the navigational signal. At many remote and mountainous locations, the airport/heliport is located beyond the navigation aid's service volume; therefore, the aid is unusable. At other sites, the locations of many navigation aids preclude the development of instrument approaches with sufficiently low weather minimums.

LORAN-C offers an alternative that will alleviate most problems associated with existing navigational aids. Its potential has long been recognized by the aviation community. The FAA still needs to resolve a number of issues before LORAN-C can be used for standard instrument approach procedures. These issues are addressed in section 4.2.2.

Another navigational system with greater accuracy and coverage capability is GPS. GPS also offers the potential to provide nonprecision instrument approaches.

While SIAPs would be useful to many rotorcraft operators, their disadvantages and limitations must also be considered. Four considerations are particularly important.

For public-use approaches to be developed, a control zone must also be established. Many of these control zones would be established in an area where surveillance at 700 feet AGL and below is not available. As a result, at the more active heliports the advantages from decreased flight disruptions could be outweighed by the disadvantages of increased flight delays to VFR/SVFR aircraft. The impact of additional control zones on the NAS must also be weighed.

Federal Aviation Regulations prohibit Federal funding for the development of instrument approaches at private-use facilities (reference 19), which comprise the vast majority of heliports. These regulations also require that heliport owners be responsible for establishing and maintaining the instrument approach. The benefit/cost analysis of nonprecision approaches to hospital heliports indicates a significant benefit to society would result. However, hospital heliports are private and therefore are currently ineligible for a government-funded approach procedure. It is questionable whether competing area hospitals would shoulder the additional costs or be sufficiently cooperative to fund these approaches.

Heliports in congested areas might be prevented from establishing instrument approaches due to a lack of sufficient airspace or because of numerous obstructions. In these cases, point-in-space approaches may provide a viable option. To be safe, the approaches must have easily navigable visual corridors with minimal obstacles that might be

a threat to the helicopter. For city center heliports, point-in-space approaches might not be an option.

There is concern in the operational community that FAA is too understaffed in flight procedures to approve the expected large influx of requests once LORAN-C and/or GPS are approved for standard instrument approach procedures. They are concerned that the bulk of new requests for instrument approaches will probably not be approved without an extended time delay.

The approval of LORAN-C and/or GPS for IFR approach procedures could have an effect on delays. Rotorcraft IFR operations will likely increase with the availability of less expensive precision and nonprecision approach procedures. As small airports/heliports service an increasing number of IFR rotorcraft and fixed-wing aircraft, delays will result due to the lack of communications or surveillance. Approach and departure delays from areas previously not used for IFR operations will increase in some areas.

3.5.3 Other Potential User Needs

The anticipated rotorcraft user needs and trends presented in the preceding sections are based on projecting existing user needs and trends into the future. Many of these forecasts would become inaccurate if new rotorcraft technologies significantly improve the aircraft's competitiveness. Such possibilities increase with the emergence of tiltrotor and tiltwing aircraft or other technologies that could substantially reduce rotorcraft operational costs or increase their range and airspeed. Forecast growth rates, on which this report's conclusions are based, might grossly underestimate future rotorcraft operations or the rotorcraft's limited reliance on IFR.

Should new technologies enable rotorcraft to become a significant factor in the United States transportation infrastructure, significant VFR and IFR operations would occur at heliports, and the need for improved CNS and air traffic control services would increase proportionally.

3.5.4 Summary

In the absence of a rotorcraft technology breakthrough, rotorcraft will continue to perform the majority of their flights under VFR, although the percentage of IFR operations will continue to increase. In most instances, their VFR needs are properly met.

The terminal IFR infrastructure could be improved to better enable rotorcraft to operate more efficiently, but before any changes are made to the IFR system, the impact on VFR operations must be considered.

4.0 NAS SYSTEMS

The NAS infrastructure is dynamic and continually acquiring new capabilities. A proper analysis of future rotorcraft operational needs and solutions must account for such dynamics. This section describes the improvements contained in the CIP and alternative CNS systems that possess the potential to enhance future rotorcraft flight.

4.1 COMMUNICATIONS SYSTEMS

The United States currently relies on ground-based facilities to support air/ground communications, with satellite-based communications offering promise for air traffic control purposes in the future. The following is a discussion of both ground-based and satellite-based systems that have potential for supporting air traffic control.

4.1.1 Remote Communications Facilities

Remote communications facilities (RCF) using very high frequency (VHF) and ultra high frequency (UHF) bands will continue as the primary air-ground communications system in United States airspace. The propagation characteristics of VHF/UHF are predictable and reliable. However, they are limited by an increasingly crowded radio frequency spectrum and by line-of-sight restrictions. These limitations, added to the cost of the system, can preclude the improvement of low altitude coverage or filling communications voids.

Remote facilities were formerly identified by function: remote communications air/ground facilities (RCAG) for Air Route Traffic Control Centers (ARTCC), remote transmitter/receivers (RTR) for terminal radar approach control facilities (TRACON) and airports, and remote communications outlets (RCO) for flight service stations (FSS). For purposes of reducing frequency interference and developing more cost-effective systems, many of these facilities are being consolidated into a single system, the RCF. RCF capabilities are also being upgraded with improved electronics that incorporate reduced bandwidths and single antennas having multiple frequency capabilities. Both improvements lessen frequency interference problems.

Line-of-sight limitations can hamper many low altitude rotorcraft operations. The FAA has a goal to provide communications coverage down to 2,000 feet AGL except in areas where there is minimal air traffic (generally in busy traffic areas, coverages are lower). Many rotorcraft VFR flights are performed below 2,000 feet, and rotorcraft operators in the Northeast must avoid icing by flying IFR at the lowest possible altitude during winter months.

For those areas where communication coverages are inadequate, the only apparent solution using current technology is to install additional RCFs or relocate existing RCFs. While the need must be justified in benefit/cost terms, frequencies have to be reallocated, and issues of

radio frequency interference must be addressed. These issues are currently reviewed by the FAA every few years, and recommendations are made to install or relocate existing RCFs.

Existing communications coverages are presented in appendix G for five areas of the United States. These areas all employ tower en route control for low altitude air traffic control and therefore use terminal communications systems. The plots show that at both 700 feet AGL and 1,200 feet AGL, communications coverages are generally excellent. A few mountainous sections of these areas do lack coverage at the selected altitudes. These coverage maps suggest that in most areas where tower en route control is employed, communications are very good at both an average en route VFR altitude (700 feet) and the lowest possible en route IFR altitude (1,200 feet).

In most areas where low altitude traffic is handled by an ARTCC, low altitude communications coverages are inferior to the areas selected for the analysis. These inferior coverages are a result of the far greater distances between RCFs employed by the ARTCC.

4.1.2 Satellite-Based Communications

The CIP does not address satellite-based communications for domestic airspace. However, the FAA is performing an ongoing detailed assessment of such a capability, and few experts would argue that it does not have a place in future aviation. Satellite-based communications would most likely be integrated into the terrestrial-based communications system and would provide coverage down to the ground in most domestic airspace, the possible exception being northern Alaska.

Several issues must first be resolved before rotorcraft will be capable of using satellite-based communications. First, existing airborne satellite antennas and avionics are unacceptably large and too heavy for rotorcraft use. These antennas are 2 feet high and more than 3 feet long. The total package of antenna, avionics, and wiring weighs more than 100 pounds. There is no available equipment for small aircraft at this time. The main barrier is that small antennas reduce reception and transmission capabilities to unacceptable signal-to-noise ratios (reference 20).

The second obstacle is data transmission rates. The FAA has proposed a reduction in the standard for ATC purposes to 9.6 kbit/s. Most experts feel a further reduction is necessary for the bandwidth and power requirements to be acceptable for the efficient use of satellites. The FAA Technical Center is continuing to investigate this issue (reference 21).

The third obstacle is cost. Should such a communications system become commercially available, the purchase cost and operating costs would be unacceptably high for commercial rotorcraft operators.

These problems may possibly be overcome with the advent of even more sophisticated technology. However, these problems are significant, and until an extensive NAS satellite-based communications infrastructure is in place, any prediction on when satellite-based communications for rotorcraft use would become available would be extremely speculative. For the time period addressed by this report, from 1990 through 2005, these obstacles will probably prevent satellite-based communications from becoming a viable option for rotorcraft.

In the interim, a number of companies are aggressively working on systems that would allow the small operator to use satellite-based communications for other than ATC purposes. Such a communications package would have the potential of increasing safety during remote area operations.

4.1.3 High-Frequency Communications

High-frequency (HF) communications are not limited to line-of-sight and can be used over longer distances than VHF. These characteristics are particularly applicable to flights performed at low altitudes or in remote areas. However, HF suffers from poor propagation reliability, and the audio quality has been determined by the FAA to be unacceptable in domestic airspace. Also, the higher wavelengths require long antennas to receive transmissions effectively.

These limitations are characteristic of HF radio waves. For the time period addressed by this report, these limitations will probably prevent HF communications from becoming a viable option for rotorcraft for all operations except those in the Atlantic and Pacific beyond domestic airspace. The FAA also does not consider HF as an option in the Gulf. HF communications for rotorcraft may prove to be of value only in the Navarin Basin (200 miles off the west coast of Alaska).

4.1.4 Summary

Three communications systems, RCF, satellite, and HF, were considered in this report. Only RCFs are considered a viable solution through the year 2005. The benefit/cost work will therefore only consider the installation of additional RCFs as a solution to coverage shortfalls for rotorcraft.

4.2 NAVIGATION SYSTEMS

The future NAS will increasingly rely on GPS and LORAN-C to supplement the standard VOR/DME. The combination of these three systems will provide rotorcraft operators with excellent navigation coverage throughout the United States.

4.2.1 VOR/DME

Nearly 1,000 VOR/DME stations are located throughout the United States and provide the basis for defining the Federal airways. These systems have high signal-to-noise ratios, high integrity, and currently provide the NAS's only primary navigation system. The accuracy of VORs is limited by line-of-sight. Terrain, manmade obstacles, and curvature of the earth restrict the usable range of the system, especially at low altitudes.

The accuracy of the VOR provides the basis of the design specifications for ATC standards and procedures. Accuracy and signal coverage are a function of altitude and distance from the station. Angular accuracy of the VOR is 1.4 degrees (± 95 percent confidence interval) from centerline. The normal service radius between 1,000 feet AGL and 18,000 feet is 40 nmi (reference 22). Below 1,000 feet AGL, the service radius decreases.

4.2.2 LORAN-C

Due to the line-of-sight limitations of VOR/DME, the rotorcraft community has increasingly equipped their aircraft with LORAN-C. Frequencies used by LORAN-C are not limited by line-of-sight. Excellent coverage is provided down to the surface over the contiguous United States, Hawaii, and the southern two-thirds of Alaska.

LORAN-C signals vary in accuracy as a function of temperature and humidity and are also vulnerable to extensive loss of coverage from the outage of a single station. The LORAN-C signal does not provide the accuracy of GPS. Absolute accuracy of LORAN-C is 0.25 nmi (± 2 distance root mean square (DRMS)). Its repeatable and relative accuracies are between 0.01 and 0.05 nmi.

LORAN-C receivers are relatively inexpensive and provide an area navigation capability (VFR and IFR) at virtually all altitudes. LORAN-C is used extensively by rotorcraft operating in areas beyond the range of VOR/DME (generally offshore and in remote areas).

The FAA has determined that before LORAN-C can be used for SIAPs, on-site LORAN-C monitors must be installed and time difference data collected for approximately 6 months. The time difference data is used to prepare calibration corrections which appear on the approach charts. Procurement of these LORAN-C monitors is an ongoing program.

Several LORAN-C instrument approaches have been published. All but two require prior approval from the source noted on the approach plate before an operator uses them. No LORAN-C receivers for instrument approach use are currently certified and probably will not be until after an "aviation blink" integrity warning is available on the LORAN-C signal. Several separate parts of the LORAN-C program must be completed to achieve program objectives (reference 27): 1) completion of new LORAN-C transmitters and modification of existing transmitters,

2) development of local area monitor receivers, 3) development and approval of LORAN-C public approach procedures, and 4) production and certification of LORAN-C instrument approach avionics.

The capability of LORAN-C to provide cost-effective, easily implementable, nonprecision instrument approaches has been acknowledged by the FAA. The FAA has already received more than 500 requests for LORAN-C approaches (even prior to the certification of a receiver for an instrument approach) and anticipates more than 3,000 additional requests will be filed within the next few years (reference 23). The development of LORAN-C approaches to helipads alone could significantly increase the number of IFR rotorcraft operations.

4.2.3 Satellite-Based Navigation Systems

Several satellite-based navigation systems offer the potential to be a global navigation system. The system of greatest interest to the FAA is the Department of Defense's global positioning system (GPS). This system will be especially beneficial to the rotorcraft community due to signal availability at all altitudes and regions. This system is expected to, at a minimum, provide supplementary navigation. Its suitability as a sole-source navigation system remains questionable. GPS also could provide a very accurate and inexpensive nonprecision approach capability.

GPS issues that remain unresolved are selective availability (intentional degradation of the signal for defense purposes), integrity, and redundancy. Some may be overcome with the integration of the GPS signal with another navigation signal such as LORAN-C or the Soviet Union's GLONASS. Combined signal processing may be adequate to support a sole means navigation system.

The navigation information provided by VOR/DME supplemented by LORAN-C and GPS will satisfy future rotorcraft user requirements for position information. It is not anticipated that operators will need further navigation-guidance information.

4.2.4 Microwave Landing Systems (MLS)

The microwave landing system (MLS) could provide the first viable precision approach system to heliports. The most important advantage of this system is its capability to provide steep angle and curved approaches to a destination, unlike the ILS which is limited to straight-in, fixed-angle approaches. This advantage is particularly amenable to rotorcraft since many heliports are situated in confined areas. Curved and steep-angle approaches would enable more efficient use of airspace and permit approach paths that would reduce environmental noise considerations.

Other advantages of MLS over ILS are equally important. The propagation characteristics of the MLS signal are rarely affected by terrain (ILS requires flat terrain with large, clear areas). Also,

MLS has been allocated 200 transmitting channels, enough for foreseeable needs, thereby eliminating frequency congestion and permitting numerous additional heliport and airport candidates.

These advantages make it a feasible precision approach system for heliports. Work is ongoing to achieve this goal. The FAA and the rotorcraft industry are resolving many issues with MLS, precision approach lighting systems, curved-path approaches, and steep-angle approaches. A heliport approach lighting system (HALS) has been defined by the FAA.

One of the concerns with implementing MLS is that GPS may also provide a precision approach capability. A GPS precision approach capability could be more cost-effective than MLS and eliminate the need for MLS avionics. These unresolved issues and the site-specific criteria required for MLS siting have made a benefit/cost analysis of MLS beyond the scope of this project.

4.2.5 Summary

The combination of VOR/DME, LORAN-C, and GPS will provide the rotorcraft community with an excellent navigation capability, even at low altitudes. For en route use, all rotorcraft navigational needs will likely be satisfied with these systems.

The FAA has encountered several issues in the approval of LORAN-C and MLS for instrument approaches. Despite the issues, the FAA plans to have both systems available within the next several years. LORAN-C, in particular, would benefit rotorcraft IFR operations, providing an inexpensive and implementable nonprecision approach capability.

4.3 SURVEILLANCE SYSTEMS

Three types of surveillance systems are currently used by ATC for separations purposes: air route surveillance radar (ARSR), airport surveillance radar (ASR), and the air traffic control radar beacon system (ATCRBS). The FAA is also developing automatic dependent surveillance (ADS) for trans-oceanic flights. Each of these systems, depending on geographic location, provides (or has the potential to provide) surveillance of rotorcraft.

4.3.1 Air Route Surveillance Radar (ARSR)

The ARSR is a long-range radar system used by the ARTCC to support low traffic density airspace. Each of these radars has an ATCRBS collocated at the site to supplement the primary-radar service. Rotorcraft IFR flight operations performed in airspace under the control of the ARTCC have surveillance provided by an ARSR. Such areas are in the Gulf of Mexico and most of the central and midwestern United States.

The ARSR capability produces a minimum aircraft separation of 5 nmi, compared to an ASR which affords 3 nmi separation due to its higher update rate and its positional accuracy at longer ranges. The limited number of ARSRs spread over broad areas also results in relatively poor low altitude coverage.

4.3.2 Airport Surveillance Radar (ASR)

In most high traffic density airspace, such as in the Northeast, ASRs provide the radar services for all low-altitude traffic. ASR also incorporates a collocated ATCRBS. The ASR is generally located at an airport and provides short-range primary radar coverage. The ASR supports the TEC system that enables TRACON facilities to control low-altitude traffic.

Based on existing benefit/cost procedures used by the FAA, the justification for the installation of an ASR is based on the number of aircraft operations at an airport.

Existing surveillance coverages are presented in appendix G for five areas of the United States. As with terminal communications, the areas selected employ TEC for low-altitude air traffic control and therefore use terminal surveillance systems. The plots show that at both 700 feet AGL and 1,200 feet AGL, surveillance coverage is generally very good, though inferior to communications coverage. However, mountainous sections in these areas frequently lack coverage at the selected altitudes. These coverage maps suggest that in most areas where tower en route control is employed, surveillance coverage satisfies rotorcraft operational needs. The sections that lack low altitude surveillance coverage also tend to be areas of low traffic densities and, therefore, improved surveillance is not necessary.

In most of the areas when low altitude traffic is handled by the ARTCC, low altitude surveillance is far inferior to the surveillance in areas selected for the analysis. This inferior coverage is a result of the substantial distances between ARSRs employed by the ARTCC.

4.3.3 Automatic Dependent Surveillance (ADS)

ADS is surveillance of an aircraft based on position data obtained by the on-board navigation system and reported automatically to ATC by the aircraft. This navigation data will be provided to en route facilities via a communications link. For oceanic routes, data will be relayed by employing satellite communications.

Two projects are currently investigating the possibility of using ADS to provide IFR separation. The project, "ATC Application of Automatic Dependent Surveillance," CIP Project 64-29, is investigating the application of ADS for transatlantic and transpacific air carrier flights. Implementation of this program could significantly increase the efficiency and safety of transoceanic flights.

The second ADS project under evaluation is "LORAN Offshore Flight Following (LOFF)," Project 64-17. This system is directly applicable to rotorcraft operations and could provide IFR surveillance in portions of the Gulf of Mexico where helicopters are supporting offshore oil and gas production. LOFF would relay LORAN-C derived latitude and longitude position to ATC using existing RCAGs located on land and offshore. Position information would therefore be available to controllers at their workstations.

4.3.4 Summary

The expense associated with improving surveillance dictates that the FAA develop a long-range plan for its improvement. Based on existing rotorcraft activity levels alone, improvements to surveillance cannot be justified except in the Gulf of Mexico.

4.4 COCKPIT-BASED SYSTEMS

Several advances in cockpit-based systems will enable rotorcraft pilots to operate more safely while operating under VFR. This technology may someday also enable rotorcraft to fly in IMC without being under the control of ATC, a postulated flight environment termed "autonomous IFR flight."

The most likely systems to enhance rotorcraft safety of flight when VFR are night vision goggles, head's-up displays, and electronic obstacle detection systems (sometimes called "visionics"). Night vision goggles have been used by the military for a number of years to aid night flights, primarily at very low altitudes. Engineering advances of these devices have improved their light-gain capabilities, increased the pilot's peripheral vision, and reduced the system's total weight. The FAA is currently testing and evaluating the application of night vision goggles for civil applications. The FAA's current focus is to enhance the safety of the EMS operator flying in remote regions of the country.

Head's-up displays (HUD) provide an image of the primary flight instruments at eye level in front of the pilot. This enables pilots to scan the flight instruments and see outside the cockpit simultaneously. This capability reduces the likelihood of a mid-air collision or an obstacle strike. HUDs can also be valuable during instrument approaches, particularly during conditions of low ceilings or poor visibility. The FAA has recognized this added capability and, as a result, only HUD-equipped airplanes can perform manual category IIIa instrument approaches.

Four obstacle detection systems have the potential to aid flight in difficult visual conditions and reduce the incidence of obstacle strikes. These systems are forward-looking infrared radar (FLIR), millimeter-wave radar (MMWR), laser radars (ladars), and low-light level television (LLLTV). Each of these devices are being studied for

their ability to forewarn pilots of hazardous obstacles and consequently increase safety.

Since some of these systems also afford pilots the capability to detect obstacles in IMC, they may reduce instrument approach visibility requirements, conceivably down to "zero-zero" conditions. Such systems may also someday enable rotorcraft pilots to develop and fly instrument approaches to any site. Conceptually, the pilot would fly a slow speed approach with one of the synthetic vision devices providing the bearing-distance information on nearby obstacles. Instrument departures from any site could be similarly developed.

This type of instrument approach is being performed by rotorcraft pilots in the Gulf of Mexico in the form of offshore standard approach procedures (OSAP) and airborne radar approaches (ARA). Weather radar in the mapping mode provides pilots with the appropriate information about nearby obstacles. Weather minimums of 250 feet ceiling and 1/2 mile visibility are authorized.

Synthetic vision devices could be supplemented with third generation traffic collision avoidance systems (TCAS III) and Mode S to provide pilots the ability to perform autonomous or semi-autonomous IFR flight. Many experts believe such a revolutionary concept is realistic. The FAA, together with the Air Line Pilots Association, is currently exploring these possibilities, with the most near-term application being transoceanic flights.

Autonomous or semi-autonomous IFR rotorcraft flight could provide rotorcraft pilots with the greatest degree of freedom to depart when they choose, fly the most direct routes, and incur the least ATC constraints. Since this type of flight is, at a minimum, several years away, it will not be further analyzed. Additional information on these cockpit-based systems is presented in reference 14.

5.0 ATC POLICY AND PROCEDURAL IMPROVEMENTS

A number of policy and procedural improvements could be adopted by the FAA to ease traffic congestion at high activity airports. Such improvements would promote rotorcraft as an alternative transportation vehicle while increasing airport capacity.

5.1 ROTORCRAFT POINT-IN-SPACE APPROACHES

VFR and SVFR flight provide the best means for rotorcraft to access high activity airports, but the difficulty in transitioning from IFR to VFR continues to pose a significant problem. A rotorcraft point-in-space approach, if properly developed, offers a simple and logical means of providing this transition and helps to relieve the delay problem at many high activity airports. A point-in-space approach has the potential to provide the key ingredient for transitioning from an IFR environment to a VFR environment. It also provides the latitude for tailoring airspace to fit the needs of both fixed- and rotary-wing aircraft with a minimum of expense.

Today's operating procedures require the use of a published instrument approach to make an IFR approach to an airport. Existing methodology forces both fast and slow aircraft to be funnelled into a single approach path, leading to traffic slow downs and delays. The result is a saturation of approach control airspace. Separate, non-interfering instrument approach procedures for fixed-and rotary-wing aircraft offer the best opportunity for alleviating this airspace saturation.

It should be noted that while rotorcraft approach speeds to a conventional runway are the same as for Category A aircraft (less than 91 knots), steep approaches to heliport/vertiports require considerably slower approach speeds. Although rotorcraft approaches to heliports/vertiports free up approach slots to a runway, capacity computations should use 60 knots as being more realistic for steep angle approaches to heliports/vertiports.

There are concerns expressed in some parts of the FAA regarding the use of point-in-space approaches. One disadvantage is that point-in-space approaches could require either enlarging the existing control zone or establishing an additional one. At many locations, the disadvantages to VFR and SVFR flight will have to be weighed against the benefits to IFR rotorcraft flights.

A second concern with point-in-space approaches is compliance with 14 CFR 91.175 (see appendix A). One requirement of this regulation is that, for civil operations below DH or MDA, the aircraft must be "continuously in a position from which a descent to a landing on the intended runway can be made at a normal rate of descent using normal maneuvers...."

Yet another concern regarding point-in-space approaches is the possibility that the rotorcraft may be placed at increased risk to obstacles during times of low ceiling and/or low visibility along the route to the intended place of landing. Night operations are of special concern.

5.2 ROTORCRAFT-ONLY STANDARD TERMINAL ARRIVALS (STARs) AND STANDARD INSTRUMENT DEPARTURES (SIDs)

STARs provide pilots with the ability to transition between an outer fix, or arrival waypoint in the en route structure, to the instrument approach. Conversely, SIDs depict routes from the airport through the terminal area to the en route structure. They permit pilots to perform their own navigation while reducing controller workload.

Conceptually, a rotorcraft STAR could be developed that originates at a feeder fix in the en route environment, and incorporates VOR/DME, area navigation (RNAV), LORAN-C, or GPS routing to a final approach fix for an independent approach to the airport. Alternatively, the routing could lead to an approach fix for a point-in-space approach. The approach would terminate in visual conditions at the edge of the airport traffic area or provide entry to the VFR route structure at points easily identifiable by landmarks.

In busy terminal areas, dedicated rotorcraft SIDs would be useful in segregating departing rotary-wing aircraft from the standard departure routes of fixed-wing aircraft. The SID could originate at the heliport/vertiport instead of the end of the runway. Helicopter in-trail departure courses on the SID should be greater than 45 degrees from the fixed-wing traffic pattern of arriving or departing aircraft to ensure adequate IFR separation. At low activity airports, exclusive rotorcraft SIDs and STARs may not be necessary unless there are significant rotary-wing/fixed-wing traffic conflicts.

5.3 PARALLEL/CONVERGING RUNWAY MONITORING (PCRM)

The FAA's investigation of increasing airport IFR capacity using closely spaced parallel runways, and converging runways is ongoing. Minimum distances between runways used simultaneously for instrument approaches may be reduced from the existing standard of 4,300 feet down to 3,000 feet. Better use of converging runways for IFR operations is also under investigation. Work is ongoing to increase this capability by increasing surveillance radar update rates, using computer-generated "ghost" aircraft and enhancing monitor systems.

The objective of the PCRM program is to establish the technical characteristics for a future radar runway-monitoring system that will permit efficient utilization of closely-spaced and converging runways during IMC. The PCRM study was initiated in 1987 under a program titled Parallel Runway Monitor (PRM) and gradually evolved from a study designed solely to improve IFR parallel runway operations to one

that can be applied to converging operations and other multiple approaches.

The PCRM program has potential benefits for rotorcraft as well as fixed-wing aircraft. PCRM permits additional runways and/or reduced separation to be used during IFR thereby increasing airport acceptance rates. Use of PCRM could also permit more efficient mixing of aircraft with differing speeds. Fast fixed-wing aircraft would use one runway and rotorcraft and slower fixed-wing aircraft would use the other runway, thereby optimizing acceptance rates at each runway.

5.4 INSTRUMENT APPROACH ROTORCRAFT INTERCEPT POINT

Another method to reduce total delays at large airports is to enable rotorcraft to intercept the final approach course at a point closer to the runway threshold. This point, called the rotorcraft intercept point, would be located inside the standard instrument approach intercept point and possibly as close as the final approach fix.

Paragraph 5-120 a.(2) of the Air Traffic Control Handbook currently permits aircraft to be vectored to the final approach fix if specifically requested by the pilot. The rotorcraft's Category A approach speeds and higher maneuverability would enable a safe approach after being vectored to a point inside the standard intercept point. The Air Traffic Control Handbook could be revised as shown below:

CURRENT	ADD
Paragraph 5-120 a(2) ...2) If specifically requested by the pilot, aircraft may be vectored to intercept the final approach course inside the gate but no closer than the final approach fix.	...(3) Rotorcraft may be vectored to intercept the final approach course inside the gate but no closer than the final approach fix with pilot concurrence.

An average instrument approach, as described by TERPS, has the final approach fix located about 5 miles from the end of the runway threshold with the intercept point situated 3 miles beyond the final approach fix. Eliminating the rotorcraft's need to fly from the aircraft intercept point to the final approach fix would save the rotorcraft and each additional in-trail aircraft a minimum of 34 seconds. A description of how this timesavings was computed is presented in appendix A of reference 14.

5.5 REDUCED SEPARATION OF IFR ROTORCRAFT

Reducing IFR arrival delays by decreasing longitudinal radar separation of IFR aircraft to less than 3 miles during IFR approaches is an ongoing program for the FAA. Improvements in aircraft position accuracy and update rates due to improved surveillance systems have led many experts to believe a reduction is achievable. From the point

of view of some controllers, reduction down to 2 miles between rotorcraft is achievable (reference 18). A few airports currently have reduced separation on final approach down to 2.5 miles. This procedure is described in FAA Handbooks 7110.65F (paragraph 5-72d) and 7210.3I, "Facility Operation and Administration" (paragraph 1236).

The main requirements of this procedure are a runway occupancy time of less than 50 seconds, runway turnoff points that are visible from the tower, and the leading aircraft's weight class being the same as or less than the trailing aircraft. All three requirements would be met at most airports, since a typical rotorcraft instrument approach is terminated with rotorcraft performing a low approach to the runway threshold and continuing on to the helipad. No requirements exist for a high speed taxiway.

Adopting this procedure would save each in-trail aircraft 16 seconds (reference 14). Such a timesavings can be significant if numerous aircraft experience this delay reduction during peak hours. Similar procedures to reduce separation between rotorcraft and in-trail aircraft are implementable based on existing requirements.

5.6 ROTORCRAFT CONTROLLER

A number of major terminal areas, including those around Boston Logan International, Washington National, and Los Angeles International Airports, have dedicated helicopter ATC positions with discrete frequencies. Most of these positions are only manned during periods of heavy traffic.

The primary benefit is reduced delays due to less communication frequency congestion and faster clearances from air traffic controllers. Rotorcraft flight paths typically are different than fixed-wing paths, and one air traffic controller can effectively handle all helicopters and reduce frequency congestion.

A secondary benefit is safety. When pilots monitor other pilots broadcasting their position, altitude, direction of flight, and intentions, they become more aware of other low altitude aircraft. Similarly, when listening to controllers issue clearances and advisories to similar operations, pilots can better anticipate other aircraft activities.

5.7 LOW ALTITUDE IFR ROTORCRAFT ROUTES

The wisdom of expanding an IFR route system for the exclusive use of rotorcraft is debatable. The benefits of such a system would be to minimize the impact of fixed-wing traffic on rotorcraft operations and to enable more direct low altitude IFR rotorcraft flight. Many rotorcraft proponents contend the rotorcraft's slower en route airspeed, higher variable operating costs, and shorter endurance necessitate this special consideration. However, a comparison of the Northeast Corridor to the VOR Federal airways and the current limited

use of the Northeast Corridor indicate the benefits derived from such a system are too small to warrant expansion into other regions of the country, (reference 18). A benefit/cost analysis will therefore not be performed on an exclusive rotorcraft IFR route system.

The Northeast Corridor has been in existence for over 15 years and was designed to demonstrate the feasibility of such a system to support IFR rotorcraft operations in high density traffic areas. It connects Washington, DC; New York, NY; and Boston, MA (and sites in between) and is the only exclusive rotorcraft IFR route system in existence except for the Gulf of Mexico. It therefore provides excellent insight into the capability of a rotorcraft-only IFR route system to satisfy user requirements.

The Northeast Corridor consists of two corridors; one supports northbound flights and the other southbound. It is considered a dynamic route structure with changes made as required and consists of 4-mile wide RNAV routes as compared to low altitude VOR Federal airways which are 8 miles wide. This reduction in width is made possible by using RNAV waypoints and route segments within 25 miles of each supporting VORTAC. This produces many closely-spaced waypoints to minimize error. Four-mile wide corridors are necessary to reduce the interference to existing low altitude Federal airways. Despite the specific goal of satisfying rotorcraft operational requirements, the Northeast Corridor is infrequently used. While some pilots use it, others believe that the routes are too far away from their origin or destination to be useful, access/egress is difficult, pilot workload is high due to the closely-spaced waypoints, and that the VOR Federal airways are adequate. In some cases, ATC controllers and helicopter operators are not even aware such a system exists.

The extent of interference from fixed-wing en route traffic is also questionable. Rotorcraft en route airspeeds vary between 90 and 150 knots, which is not significantly slower than many airplanes that operate at low altitudes. The many IFR altitudes also eliminate bottlenecking problems in en route airspace and enable air traffic control to permit aircraft to overtake each other without causing delays.

In a few terminal areas and adjacent airspace, the VOR Federal airways are restricted from use by both fixed-wing and rotary-wing aircraft. One such example is the airspace to the northeast of LaGuardia and John F. Kennedy International Airports. Rotorcraft pilots flying in this area are frequently frustrated in their attempts to fly directly northeast/southwest. Instead of flying the Federal airways as filed, air traffic control reroutes them to the airspace over Long Island where they are integrated into more congested traffic flows. For example, flying the most direct VOR airway from Hartford, CT to an initial approach fix at LaGuardia International Airport would take 40 minutes while the rerouted flight is 55 minutes. For rotorcraft operators, with limited usable fuel aboard and alternate airport requirements, the additional 15 minutes can prevent an IFR flight. If

the flight is performed, the extra 15 minutes results in 38 percent higher operational costs.

A number of rotorcraft pilots operating in this area find the rerouting costly, unnecessary, and unacceptable. They are actively pursuing the development of an additional route in the Northeast Corridor that will permit them to fly directly between origin and destination. However, from the air traffic controller's point of view, there is no distinction between a rotorcraft flying the VOR Federal airways or the Northeast Corridor. The problem remains the same: how to safely and efficiently integrate them into the traffic flow in the vicinity of high traffic airports. The most promising answer, independent of which airway system is used, is to develop rotorcraft standard terminal arrival routes (STARs), rotorcraft point-in-space instrument approaches, and rotorcraft standard instrument departures (SIDs) that fully utilize the rotorcraft's capabilities and the available airspace.

Because the problem is in the vicinity of high traffic airports, effectively using the VOR Federal airways in conjunction with TEC still remains a viable option. The Federal airways usually provide excellent flexibility and relatively direct routing. TEC affords excellent communications and surveillance coverage down to the minimum en route altitude and/or minimum obstruction clearance altitude in virtually all high traffic areas. Improving the VOR Federal airways and ATC procedures to better support rotorcraft operations provides the most viable and economical solution.

5.8 CHARTED VFR HELICOPTER ROUTES

Helicopter routes have been published for New York; Baltimore-Washington; Chicago; Los Angeles; and Boston. In these areas, operators and controllers praise their effectiveness. The same system of publicly charted helicopter routes could be developed for other areas where helicopter operators experience delays due to an inadequate helicopter route structure.

Change 3 to the FAA "Facility Operation and Administration Handbook," 7210.3I, provides instruction on the Helicopter Route Chart Program. The policy section states, "The Helicopter Route Chart Program has been established to enhance helicopter access into, egress from, and operation within high density traffic areas by establishing and charting discrete and/or common use helicopter routes, operating zones, and, where necessary, radio frequencies. The program has been designed to improve operational safety in areas where significant helicopter operations occur, and to establish a systematic process for chart development, modification, and acquisition."

Handbook 7210.3I further states: "The routes that comprise a helicopter route chart should avoid the flow of IFR traffic and will normally be derived from existing FAA-operator letters of agreement. However, these routes may be expanded to permit transitions to, from,

and between designated IFR routes and operational heliports/helistops, or to enable operators to circumnavigate designated operating areas when required."

Technically, helicopter route charts are for VFR use. However, the route charts can be used to provide SVFR clearances when approved by air traffic facility managers. The existing routes charts have been so approved. Benefits will therefore be computed in the benefit/cost analyses assuming rotorcraft can use these charts to operate SVFR in a control zone.

6.0 BENEFIT/COST ISSUES

The benefit/cost methodology to assess equipment and procedural improvements for rotorcraft operations was presented in reference 14. This section presents results of applying the methodology to specific sites.

Two techniques were used to apply the benefit/cost methodologies. The first technique was one for which rotorcraft operational data was available and notable benefits were achieved. In this case, the actual benefits were calculated and analyzed. At sites where rotorcraft operational data was unavailable or benefits were too small to be significant, projections of rotorcraft operational counts necessary to achieve significant benefits (benefits equal to costs) were used.

Four data sources that are accessible by the public were used to quantify the benefits in this report. FAA Air Traffic Activity for fiscal year 1989 (reference 24) is the source for all data on the number of IFR operations in an area. The Journal of Air Medical Transport is the source for the number of patient transports conducted per year in a geographic area. The FAA's Airport Specific File is the source for the weather data. Finally, instrument approach procedure charts were used to provide data for airport runway configurations.

The growth rates projected for each mission are included in this methodology. The air taxi, business, and corporate missions are escalated at 2.7 percent per year growth and the commuter mission is escalated at 3.7 percent per year growth (reference 5). Benefits from year 1 through 15 are discounted at 10 percent per year using the mid-year convention to calculate the present value of future year benefits.

A summary of the weather minimums used in the analysis and the rationale for choosing these minimums are contained in table 5. A more complete discussion of the rationale can be found in reference 14.

6.1 TERMINAL COMMUNICATIONS

Improving air/ground communications at a heliport or airport results in ATC being able to apply, at a minimum, nonradar separation services. The largest benefits that result are a consequence of reduced delays and disruptions. These are the only benefits that are computed in the methodology. While other benefits result, most notably collision avoidance, these other benefits are proportionally very small when compared to the benefits attributable to decreased delays and disruption.

The number of rotorcraft operations at heliports and airports without sufficient communications coverage is unavailable. For this reason, the results were calculated using a break-even analysis (benefit/cost

TABLE 5 SUMMARY OF MINIMUMS USED IN THE BENEFIT/COST ANALYSIS

BENEFIT	WEATHER MINIMUMS		RATIONALE	
	UPPER	LOWER	UPPER	LOWER
Terminal Communications and Terminal Surveillance	800:1	466:0.75	Pilots will operate VFR above 800:1 Typical operator's day VFR minimums	Average rotorcraft nonprecision approach minimums
Nonprecision Approaches and Point-in-Space Approaches	1,000:2	466:0.75	Itinerant traffic will begin using the IFR approach when minimums drop below 1,000:2	Average rotorcraft nonprecision approach minimums
Offshore En Route Surveillance	800:1	250:0.75	Typical operator's day VFR minimums	Typical offshore operator's airborne radar approach minimums
Rotorcraft Intercept Point and Reduced Rotorcraft Separation Procedures	1,000:2	200:0.5	Itinerant traffic will begin using the IFR approach when minimums drop below 1,000:2	Rotorcraft require precision approach runway

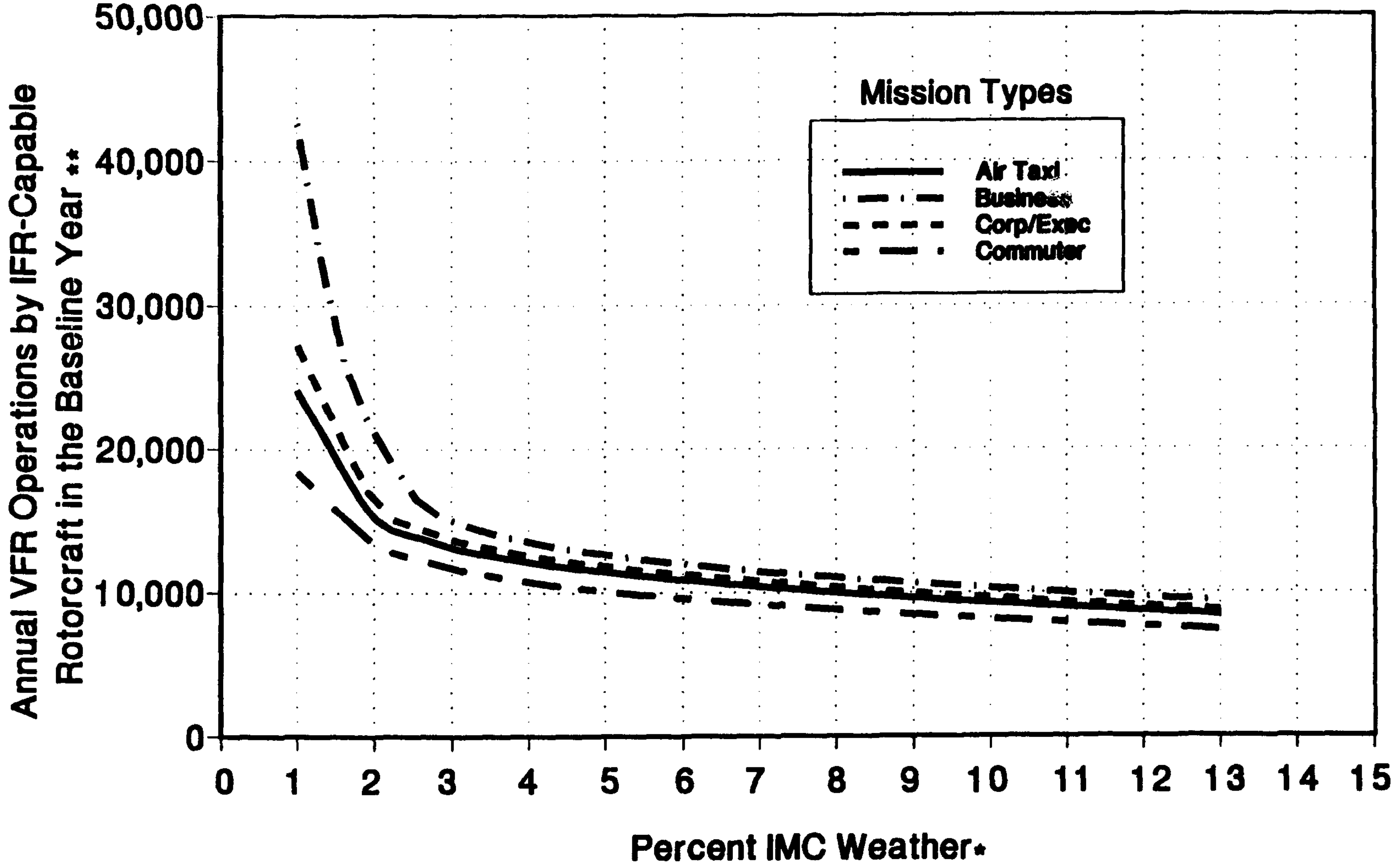
ratio = 1), with percent IMC being the independent variable. Figure 19 presents the break-even curves (benefit/cost ratio = 1) for air taxi, business, corporate/executive, and commuter missions. Because EMS missions can receive priority handling by ATC, if requested, no terminal communications benefits were calculated for EMS missions.

The break-even curves in figure 19 show that the number of annual operations by IFR-capable helicopters required to justify installation of a remote communications facility decreases rapidly as the percentage of IMC weather increases. To explain the rather complex relationships related to terminal area capacity in IMC, a detailed discussion of terminal communication and terminal surveillance benefits is contained in appendix B. Also a detailed example of terminal communications benefit calculations is presented in figure C-1 of appendix C.

The curves in figure 19 make distinct bends at approximately 2.25 percent IMC weather. These bends represent the points where delays become so lengthy that some flights are canceled. The rate of rotorcraft operations when delays become costly enough to justify canceling a flight was computed to be 5.2 operations per hour (appendix B). Any additional rotorcraft requesting an IFR approach or departure at heliports without ATC communications would be delayed so much that operators would consider canceling, diverting, or holding the helicopter at the originating heliport.

The number of annual operations by IFR-capable rotorcraft required to support terminal communications (at the break even level, benefits/ costs = 1) at potential IFR heliport sites throughout the United States is presented in table 6. Rotorcraft operations in future years are assumed to grow at the rotorcraft growth rate described in section 6.0. The number of annual operations by IFR-capable rotorcraft per year needed to justify a remote communication facility (RCF) (cost = $413,181) is not extremely large. For the air taxi mission, the number of operations needed per installation ranges from 9,385 for Barrow, Alaska with 11.3 percent IMC weather, to 19,863 for Utah County, Utah with 1.5 percent IMC weather. The remaining columns in table 6 provide the break-even number of operations for the other missions. Many locations in the counties listed in table 6 have adequate ATC communications coverage at potential heliport locations (for some specific examples, see appendix G). The operations listed in table 6 only apply to specific heliport locations that do not have adequate ATC communications.

If more than one mission type is performed at a heliport, the number and percentage of IFR operations for each mission must be determined. Following the steps outlined in appendix C, figure C-1, the sum of the operations for all missions is used to determine annual delays and diversions. Then, percentage



* Below 800 feet and 1 mile, and above 466 feet and 3/4 of a mile.

** Future year operations increase at the assumed mission growth rate.

FIGURE 19 TERMINAL COMMUNICATIONS BREAK-EVEN ANALYSIS

TABLE 6 BREAK-EVEN ANALYSIS FOR TERMINAL COMMUNICATION
Required Number of Annual VFR Operations by IFR-Capable Rotorcraft (per operation)*

COUNTY	STATE	AIR TAXI	BUSINESS	CORPORATE	COMMUTER
ANCHORAGE	AK	17,543	28,985	20,162	15,130
BARROW	AK	9,385	10,423	9,740	8,253
ALAMEDA	CA	12,429	13,964	12,905	11,026
LOS ANGELES	CA	11,138	12,261	11,496	9,811
RIVERSIDE/ SAN BERNADINO	CA	11,004	12,108	11,361	9,688
SAN DIEGO	CA	12,530	14,115	13,022	11,136
DENVER	CO	17,297	28,580	19,948	15,054
WASHINGTON	DC	13,277	15,357	13,857	11,845
FULTON	GA	12,678	14,336	13,164	11,277
GWINNETT	GA	12,688	14,351	13,176	11,283
COOK	IL	12,218	13,651	12,662	10,809
MARION	IN	12,132	13,524	12,564	10,740
CAMERON	LA	12,688	14,351	13,176	11,283
IBERIA	LA	12,816	14,572	13,322	11,387
JEFFERSON	LA	13,826	16,322	14,489	12,344
LAFAYETTE	LA	12,816	14,572	13,322	11,387
ORLEANS	LA	13,826	16,322	14,489	12,344
ST MARY	LA	12,816	14,572	13,322	11,387
TERREBONNE	LA	13,826	16,322	14,489	12,344
VERMILLION	LA	12,816	14,572	13,322	11,387
ESSEX	MA	12,816	14,572	13,322	11,387
HAMPDEN	MA	13,150	15,077	13,672	11,712
MIDDLESEX	MA	12,816	14,572	13,322	11,387
SUFFOLK	MA	12,341	13,834	12,805	10,926
BALTIMORE	MD	13,137	15,058	13,658	11,704
WAYNE	MI	12,250	13,698	12,699	10,851
ST LOUIS	MO	12,964	14,796	13,492	11,536
HILLSBOROUGH	NH	12,688	14,351	13,176	11,283
ROCKINGHAM	NH	12,816	14,572	13,322	11,387
ATLANTIC	NJ	12,530	14,115	13,022	11,136
ESSEX	NJ	11,923	13,271	12,350	10,529
HUDSON	NJ	12,063	13,458	12,512	10,693
MIDDLESEX	NJ	12,194	13,615	12,635	10,797
MORRIS	NJ	11,923	13,271	12,350	10,529
UNION	NJ	12,465	14,018	12,947	11,046
NASSAU	NY	12,816	14,572	13,322	11,387
NEW YORK	NY	12,063	13,458	12,512	10,693
ROCKLAND	NY	12,194	13,615	12,635	10,797
SUFFOLK	NY	12,456	14,005	12,937	11,041
WESTCHESTER	NY	12,063	13,458	12,512	10,693
ALLEGHANY	PA	12,132	13,524	12,564	10,740
PHILADELPHIA	PA	12,598	14,216	13,072	11,203
BRAZORIA	TX	12,719	14,398	13,211	11,301
DALLAS	TX	14,272	17,372	15,004	12,765
GALVESTON	TX	12,719	14,398	13,211	11,301
HARRIS	TX	12,719	14,398	13,211	11,301
JEFFERSON	TX	12,688	14,351	13,176	11,283
UTAH	UT	19,863	32,923	22,661	15,976
KING	WA	12,698	14,367	13,187	11,289

* First year operations; operations in subsequent years will reflect growth rates unique to mission type, as discussed in section 6.0.

weighted delay and diversion cost coefficients are calculated using table 2. These weighted co-efficients are then multiplied by the calculated delays and diversions to determine the dollar benefits. These benefits are then divided by the RCF costs to determine the benefit/cost ratio for mixed missions.

6.2 NONPRECISION APPROACHES

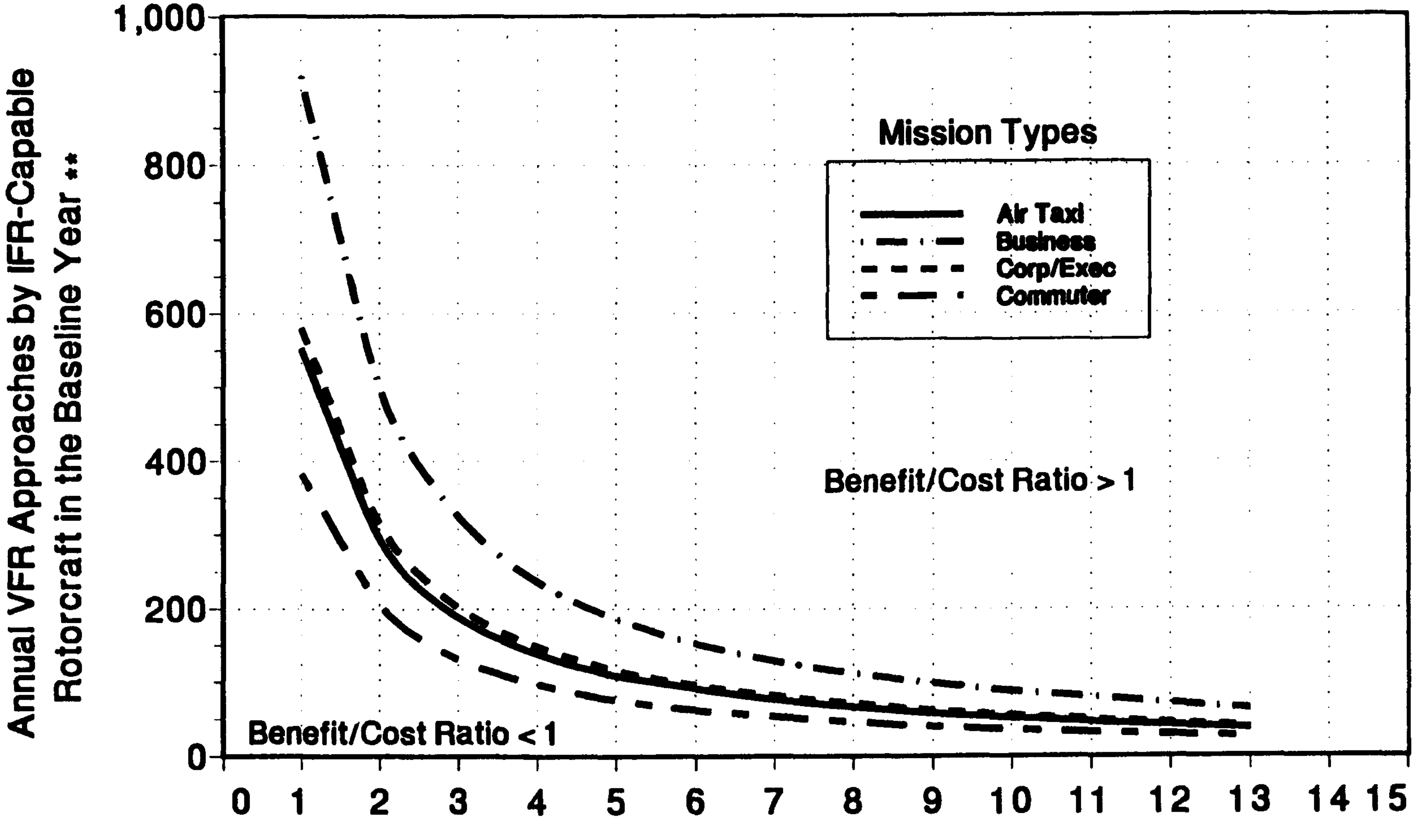
The introduction of nonprecision approaches to heliports and hospital helipads can generate significant benefits for both the helicopter operator and society. The benefits for the operator come from decreasing flight disruptions during IMC. The benefits for society come for saving additional lives by extending EMS helicopter operations into IMC. Separate methodologies capture the different benefit types. These methodologies are discussed in the following sections.

6.2.1 Benefits to Missions Other than EMS

The addition of nonprecision instrument approaches in areas lacking an instrument approach capability can decrease flight disruptions during IMC. Figure 20 depicts the break-even curves. Use of figure 20 produces the required number of annual VFR approaches flown by IFR-capable aircraft. For analysis purposes, an estimate of this statistic can often be made by multiplying the number of annual VFR approaches to a heliport by the percentage of rotorcraft using the facility that are IFR-capable. The methodology also assumes that the instrument approach procedure would have average rotorcraft instrument approach minimums. For this study, the point-in-space approach was assumed to be beneficial when the weather is below 1,000 feet ceiling and 2 miles visibility but at or above 466 feet and 3/4 mile. Appendix D presents a methodology for determining the increased number of operations that would result from providing an instrument approach capability at heliports and airports that currently have no instrument capability.

Based on the site specific break-even analysis presented in table 7, most sites serving IFR-capable rotorcraft would qualify for an instrument approach. For the business mission, the number of current annual VFR operations required ranges from a high of 496 in Utah County, Utah to a low of only 56 in Barrow, Alaska. A numerical example of the methodology is presented in appendix C, figure C-4. For locations having mixed missions, the total benefits at a site can be computed by summing the benefits from each missions' alleviated disruptions.

Discussions with operators confirm the conclusions from the benefit/ cost methodology. Operators in many areas desire an instrument approach capability. An increase in the number of rotorcraft nonprecision instrument approaches may well be accompanied by an increase in rotorcraft IFR activity levels.



* Below 1,000 feet and 2 miles, and above 466 feet and 3/4 of a mile.

** Future year operations increase at the assumed mission growth rate.

FIGURE 20 NONPRECISION APPROACH BREAK-EVEN ANALYSIS FOR MISSIONS OTHER THAN EMS

TABLE 7
ANNUAL VFR APPROACHES BY IFR-CAPABLE ROTORCRAFT REQUIRED FOR NONPRECISION APPROACH BREAK-EVEN

COUNTY	STATE	BUSINESS	AIR TAXI	CORPORATE	COMMUTER
ANCHORAGE	AK	432	256	272	176
BARROW	AK	56	34	36	23
ALMEDA	CA	168	100	104	68
LOSANGELES	CA	104	62	66	44
RIVERSIDE/	CA				
SAN BERNADINO	CA	100	60	64	42
SAN DIEGO	CA	172	104	108	72
DENVER	CO	432	256	272	176
WASHINGTON	DC	216	128	136	88
FULTON	GA	176	104	112	74
GWINNETT	GA	176	108	112	74
COOK	IL	152	92	96	64
MARION	IN	152	88	96	62
CAMERON	LA	176	104	112	74
IBERIA	LA	184	108	116	76
JEFFERSON	LA	240	144	152	100
LAFAYETTE	LA	184	108	116	76
ORLEANS	LA	240	144	152	100
ST MARY	LA	184	108	116	76
TERREBONNE	LA	240	144	152	100
VERMILLION	LA	184	108	116	76
ESSEX	MA	192	116	124	80
HAMPDEN	MA	208	120	128	84
MIDDLESEX	MA	192	116	124	80
SUFFOLK	MA	160	96	100	66
BALTIMORE	MD	200	120	128	84
WAYNE	MI	156	92	100	64
ST LOUIS	MO	192	116	124	80
HILLSBOROUGH	NH	176	104	112	74
ROCKINGHAM	NH	192	116	124	80
ATLANTIC	NJ	168	100	108	70
ESSEX	NJ	140	84	88	58
HUDSON	NJ	148	88	92	60
MIDDLESEX	NJ	152	92	96	62
MORRIS	NJ	140	84	88	58
UNION	NJ	168	100	104	68
NASSAU	NY	192	116	124	80
NEWYORK	NY	148	88	92	60
ROCKLAND	NY	152	92	96	62
SUFFOLK	NY	164	96	104	68
WESTCHESTER	NY	148	88	92	60
ALLEGHANY	PA	152	88	96	62
PHILADELPHIA	PA	176	104	108	72
BRAZORIA	TX	180	108	112	74
DALLAS	TX	272	160	176	112
GALVESTON	TX	180	108	112	74
HARRIS	TX	180	108	112	74
JEFFERSON	TX	176	104	112	74
UTAH	UT	496	288	304	200
KING	WA	176	104	112	72

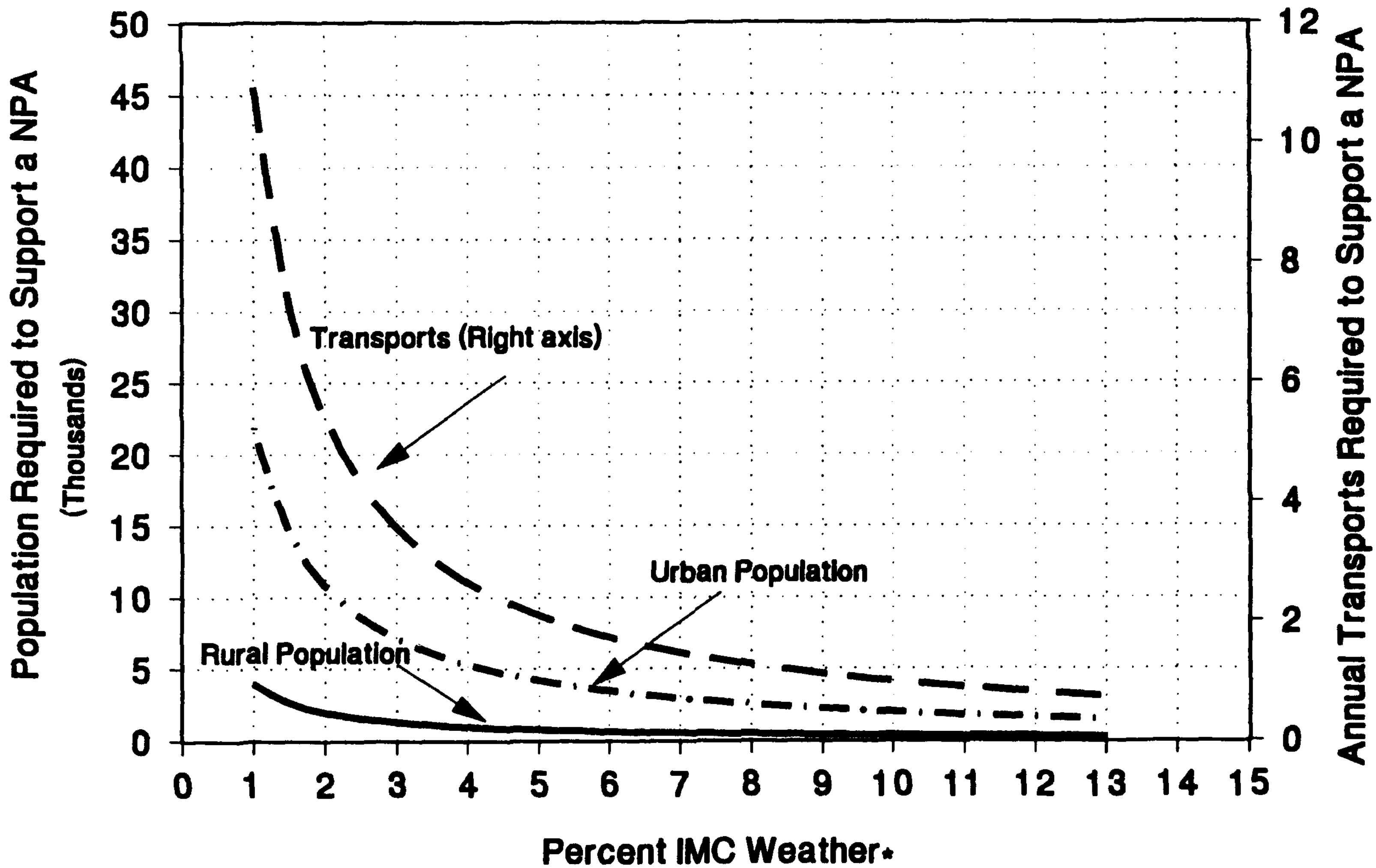
6.2.2 EMS Mission Benefits

Benefits of providing nonprecision instrument approaches to EMS hospitals are sizable due to reduced patient mortality due to improved transportation capability. A detailed explanation of the EMS benefit/cost methodology is presented in appendix D of reference 14. Figures 21 through 23 depict the results of applying this methodology.

The EMS literature describes operations in both rural and urban areas; however, the literature does not clearly define what is "rural" and what is "urban." For purposes of this study, the authors define urban areas as areas defined by the U.S. Census Bureau as standard metropolitan statistical areas. All other areas are considered to be rural.

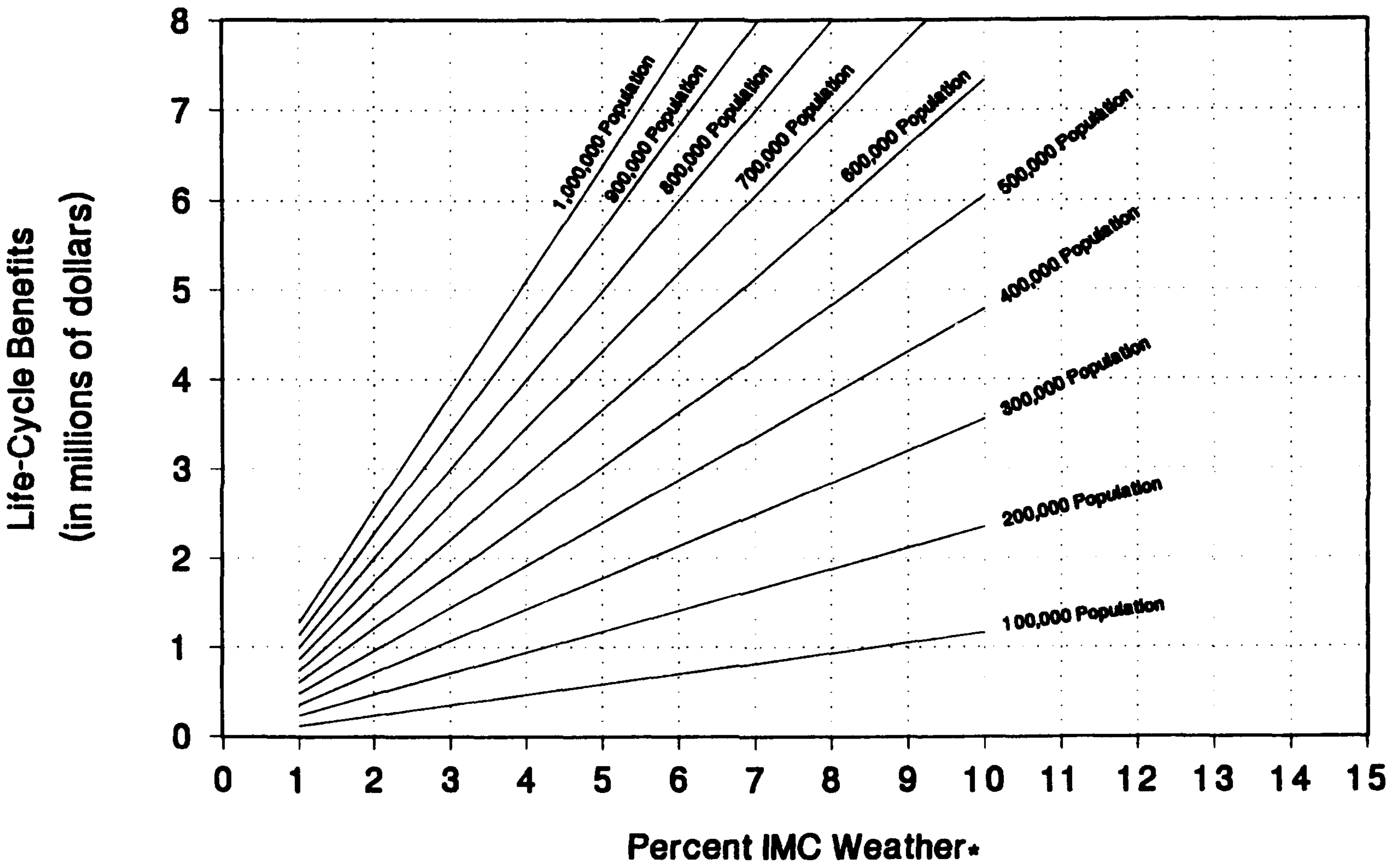
While the percent of time that weather is IMC is an algorithm variable, the most important variable is the number of annual patient transported in an area. Actual numbers of transports are available from the Journal of Air Medical Transport. Table 8 shows EMS transports in calendar year 1990, the first year benefit, the benefit over a 15-year period, and the benefit/cost ratio for each site. If actual transports are available for a site, they are listed. Otherwise, the column contains an asterisk and the benefit is calculated on the national average of the number of annual transports per 100,000 population as explained in section 8.3.4 of reference 14. This methodology determines the benefits for operating at all hospital heliports in the EMS service area. To determine the benefit/cost ratio at each site, the ratio must be divided by the number of hospital heliports in the service area that contribute to the number of annual transports, as indicated in the last column of table 8. A numerical example of the methodology is presented in appendix C, figure C-5. Effective EMS operations require that instrument approach capabilities are available at both the hospital where the patient is picked up and the hospital where the patient is delivered. In other words, an IFR system is required.

The first year benefit, even for areas of low population, exceeds the 15-year costs of a nonprecision approach. The 15-year benefit/cost ratios range from a high of 8,441/H to 1 for Riverside, CA to a low of 24/H to 1 for Cameron, LA. No growth in the number of annual number of patients is assumed. Riverside and San Bernadino, CA are one Standard Metropolitan Statistical Area. Therefore, the benefit calculated is the same for both areas. To demonstrate the dramatic impact of theses statistics in terms of lives saved, the $251,400,524 benefit for Riverside represents the saving of 167 lives over 15 years and is based on the current statistical value of $1.5 million per life (based on Federal benefit cost guidelines in reference 8). **(It should be noted that this value has recently been increased to $2.5 million (see section 1.0 and reference 33).)**



* Below 1,000 feet and 2 miles, and above 466 feet and 3/4 of a mile.

FIGURE 21 NONPRECISION APPROACHES TO HOSPITALS, BREAK-EVEN ANALYSIS



* Below 1,000 feet and 2 miles, and above 466 feet and 3/4 miles.

FIGURE 22 NONPRECISION APPROACHES TO HOSPITALS, BENEFITS FOR URBAN EMS OPERATIONS

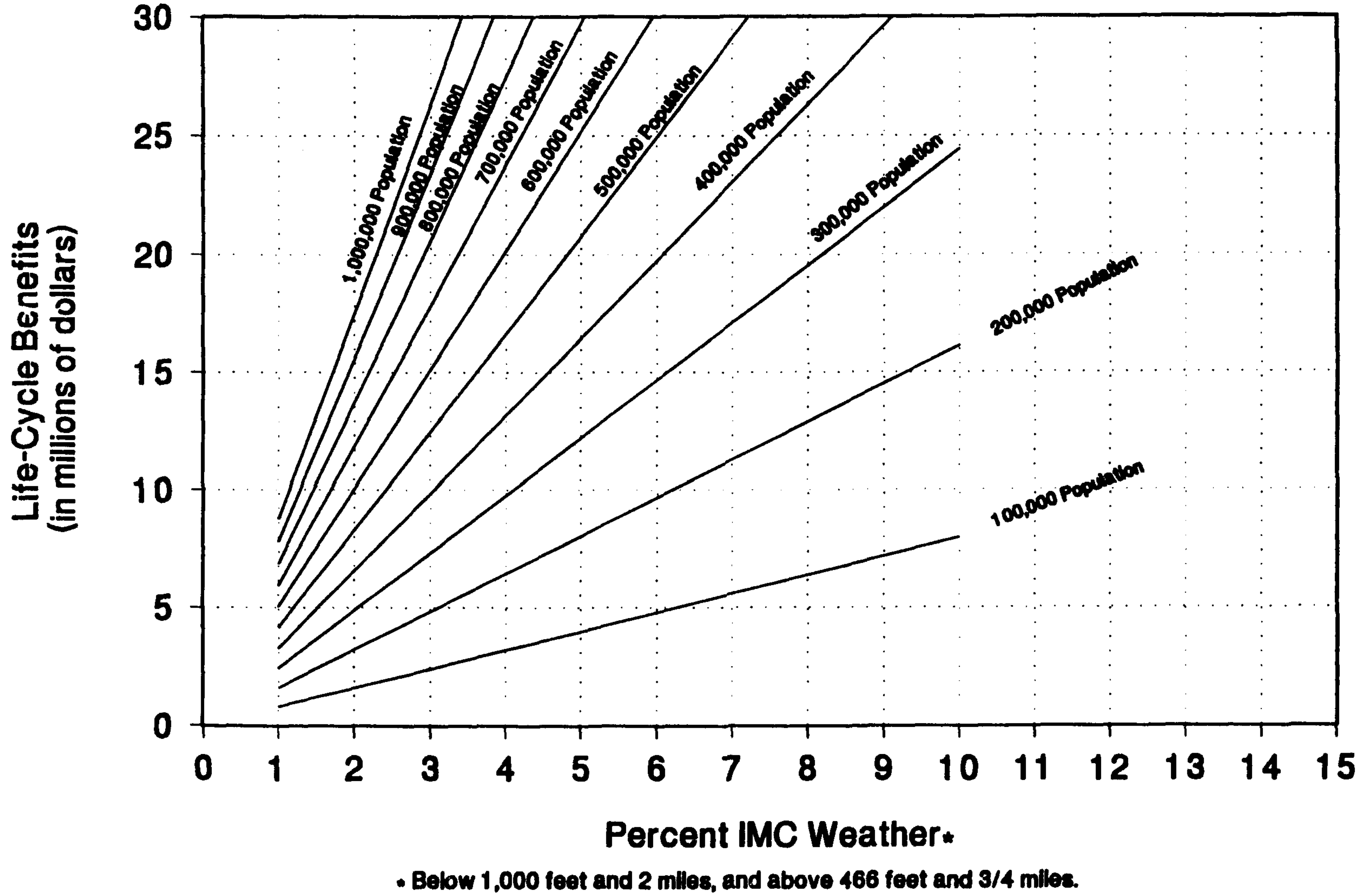


FIGURE 23 NONPRECISION APPROACHES TO HOSPITALS, BENEFITS FOR RURAL EMS OPERATIONS

TABLE 8

EMS NONPRECISION APPROACH BENEFITS FOR URBAN AREAS (1990 Dollars)

COUNTY	STATE	1990 EMS TRANPORTS	1ST YEAR BENEFITS	LIFE CYCLE BENEFITS	B/C RATIO**
ANCHORAGE	AK	176	246,857	1,969,919	66/H
BARROW	AK	*	136,946	1,092,829	37/H
ALMEDA	CA	1,766	6,600,058	52,668,463	1768/H
LOS ANGELES	CA	1,686	10,148,470	80,984,791	2719/H
RIVERSIDE/	CA				
SAN BERNADINO	CA	*	31,503,825	251,400,524	8441/H
SAN DIEGO	CA	1,832	6,606,447	52,719,447	1770/H
DENVER	CO	2,092	2,909,853	23,220,627	780/H
WASHINGTON	DC	2,360	6,646,016	53,035,208	1781/H
FULTON	GA	669	2,256,023	18,003,064	605/H
GWINNETT	GA	*	1,547,798	12,351,428	415/H
COOK	IL	610	2,444,067	19,503,655	655/H
MARION	IN	900	3,706,313	29,576,378	993/H
CAMERON	LA	*	88,628	707,251	24/H
IBERIA	LA	*	580,284	4,630,666	156/H
JEFFERSON	LA	243	602,150	4,805,157	161/H
LAFAYETTE	LA	1,200	3,971,872	31,695,539	1064/H
ORLEANS	LA	620	1,536,349	12,260,065	412/H
ST MARY	LA	*	584,844	4,667,055	157/H
TERREBONNE	LA	*	643,236	5,133,023	172/H
VERMILLION	LA	*	441,075	3,519,779	118/H
ESSEX	MA	*	5,518,183	44,035,100	1479/H
HAMPDEN	MA	*	3,625,419	28,930,844	971/H
MIDDLESEX	MA	723	2,289,467	18,269,947	613/H
SUFFOLK	MA	650	2,505,015	19,990,020	671/H
BALTIMORE	MD	3,467	10,251,305	81,805,414	2747/H
WAYNE	MI	1,616	6,363,605	50,781,568	1705/H
ST LOUIS	MO	1,704	5,305,283	42,336,158	1421/H
HILLSBOROUGH	NH	*	2,576,631	20,561,515	690/H
ROCKINGHAM	NH	*	1,657,564	13,227,361	444/H
ATLANTIC	NJ	*	23,442,708	187,072,810	6281/H
ESSEX	NJ	*	10,342,096	82,529,926	2771/H
HUDSON	NJ	370	1,546,071	12,337,647	414/H
MIDDLESEX	NJ	*	10,266,389	81,925,784	2751/H
MORRIS	NJ	*	4,952,107	39,517,814	1327/H
UNION	NJ	*	18,842,625	150,364,148	5049/H
NASSAU	NY	*	23,392,861	186,675,031	6268/H
NEW YORK	NY	422	1,763,357	14,071,589	473/H
ROCKLAND	NY	*	2,896,126	23,111,085	776/H
SUFFOLK	NY	*	27,462,853	219,153,567	7358/H
WESTCHESTER	NY	*	9,958,151	79,466,045	2668/H
ALLEGHANY	PA	3,623	14,919,969	119,061,353	3998/H
PHILADELPHIA	PA	1,955	6,875,763	54,868,589	1842/H
BRAZORIA	TX	*	1,908,758	15,231,889	511/H
DALLAS	TX	2,706	5,992,524	47,820,342	1606/H
GALVESTON	TX	*	2,018,715	16,109,346	541/H
HARRIS	TX	1,757	6,004,542	47,916,245	1609/H
JEFFERSON	TX	512	1,767,452	14,104,267	474/H
UTAH	UT	*	835,486	6,667,178	224/H
KING	WA	1,352	4,684,720	37,384,066	1255/H

* Indicates actual EMS transport data was not available, and calculations are based on the national average of annual transports per 100,000 population for urban areas.

** To determine the actual benefit/cost ratio per helipad, divide by the number of hospital heliports (H) that support the EMS operation.

In many areas, a number of instrument approaches would have to be developed to provide helicopters with an interhospital IFR capability. The calculated benefit will obviously have to be spread over the number of hospital helipads that generate the overall number of patient transports. The benefits to society are large and the development of these approaches can be justified. However, current Federal regulations preclude the FAA from using public funds to develop approaches at private heliports. Hospital heliports are currently considered as private facilities even when they are publicly owned.

6.3 SURVEILLANCE

Providing surveillance services to IFR rotorcraft allows reduced separation and reduces delays in congested airspace. Surveillance benefits in terminal and en route airspace are considered.

6.3.1 Terminal Surveillance Benefits

Improving terminal surveillance coverage at a heliport or at an airport enables ATC to provide radar separation services to IFR aircraft. The primary benefits are due to the resultant reduction in aircraft delays and disruptions.

For terminal surveillance, the relationship between percentage of IMC weather and the number of operations to break even (or to achieve a given percentage of surveillance system costs) is similar to that for terminal communications. This relationship is discussed in appendix B.

Application of this methodology to specific sites indicates that rotorcraft alone do not have sufficient IFR operations to qualify for the establishment of a terminal radar. For this reason, a detailed analysis of terminal radar establishments is not provided in this report. It should be noted, however, that rotorcraft benefits can contribute to the establishment of a radar at a nearby site. The methodology for determining this contribution is contained in the ASR-9 investment criteria, reference 29. It should be noted that rotorcraft operating costs contained in this document are somewhat dated as reference 29 was published in 1983. More current rotorcraft operating costs are found in table 2, section 3.3 of this report.

6.3.2 En Route Surveillance Benefits

A survey of United States helicopter operators indicated that en route surveillance coverage is adequate over CONUS. However, delays caused by lack of surveillance coverage were identified over the Gulf of Mexico. These delays are associated with the number of aircraft that can be accommodated by the Gulf route structure. Since there are currently 20 routes in the Gulf, the delay costs are not escalated exponentially as was done for terminal communications. Instead, the amount of delay associated with IMC weather for a documented number of

IFR-certificated helicopters is increased linearly in direct proportion to the increase in the number of IFR-certificated rotorcraft operating in the Gulf. Thus, this is a conservative estimate of the increasing amount of delay associated with additional rotorcraft wanting to operate in the same airspace. Since reliable data is available, the actual benefit for the entire Gulf of Mexico is calculated. This methodology and all benefit/cost data are documented in reference 14, section 8.3.3.

Table 9 shows the benefit/cost analysis of installing either a LOFF or an ASR-9 radar system to cover the entire Gulf. In order for LOFF to cover the entire Gulf, it would be necessary to install three additional remote transmitter receiver facilities (RTRs) in the Gulf and the associated equipment to convert LOFF position data into a pseudo-radar message for display on an air traffic control screen. The total cost for this equipment would be approximately $3.37 million. The benefits associated with the LOFF system would be approximately $15.9 million (appendix C, figure C-3 and table C-1); thus, the benefit/cost ratio is 4.7 to 1. The benefits minus the costs indicate a net benefit of $12.5 million over 15 years.

TABLE 9 SURVEILLANCE IN THE GULF OF MEXICO

SYSTEM	COST	BENEFIT	BENEFIT/COST RATIO	BENEFIT MINUS THE COST
LOFF	$ 3.4m	$15.9m	4.7	$12.5m
ASR-9	$48.0m	$22.9m	0.48	$(25.1m)

Three surveillance radars would be required to cover the majority of helicopter routes in the Gulf of Mexico. The life cycle costs of these radars would be at least $48.0 million (appendix F). The benefit associated with the ASR-9 system would be approximately $22.9 million (appendix C, table C-2); thus, the benefit/cost ratio is .48 to 1. In benefit/cost terms, LOFF is the superior system. However, the costs assigned to the LOFF system considered LORAN-C receiver costs and LOFF transponder costs to be sunk costs, because the Gulf operators indicated most of their helicopters already have LORAN-C receivers and they will probably implement a LOFF system for their own tracking purposes fairly soon. If they do not do this, then the costs of the LOFF transponders should be included in the LOFF life-cycle costs. It is estimated that the LOFF transponders would add another $1.7 million to the life cycle cost of LOFF and reduce the benefit/cost ratio to 4.5 to 1.

GPS receivers could be used in place of the LORAN-C receivers in a dependent surveillance similar to LOFF. It is expected that a GPS dependent surveillance system would have benefit/cost ratios similar to those of LOFF.

Benefit/cost ratios were not computed for en route surveillance in other areas of the country since insufficient benefits could be attributed to improved rotorcraft operations.

6.4 IMPROVED ATC PROCEDURES

Three improved ATC procedures are recommended to enhance rotorcraft operations. These procedures are most applicable at major airports that experience congestion. The first involves developing a rotorcraft instrument approach that would remove rotorcraft from the fixed-wing instrument approach pattern. The other two would decrease delays by reducing delays when rotorcraft fly the same approach as fixed-wing aircraft. A detailed analysis of the methodology is presented in appendix E and appendix C, figures C-6 through C-8.

The first improvement is the development of a rotorcraft point-in-space approach. Figure 24 presents the resulting life-cycle benefits for a rotorcraft instrument approach based on the total number of instrument operations, both fixed- and rotary-wing, during the baseline year. In the calculation of this benefit, a 2.4 percent growth rate in air carrier and general aviation traffic and a 2.7 percent growth rate in rotorcraft traffic was assumed.

For example, Dulles International Airport recorded 235,068 instrument operations in 1989, with 60 percent being air carriers (reference 24). This airport provides simultaneous parallel instrument operations; therefore, an average of 117,534 annual instrument operations are performed per runway. Assuming 1 percent of the operations are performed by rotorcraft and that national average weather minimums are applicable, figure 24 shows that 117,534 annual instrument operations and a 60-40 mix would result in a life-cycle benefit in excess of $100,000 for each of the IFR runways if rotorcraft were given a separate instrument approach procedure.

Table 10 presents the site-specific calculations based upon actual weather data and annual IFR operations. The calculations assume that IFR rotorcraft operations equal 6 percent of the annual GA IFR operations. The 6 percent ratio of rotorcraft to total GA operations is based on national average flight hours data for turbine rotorcraft from several annual FAA surveys of general aviation. This method is presented as one alternative to generate rotorcraft operations data in the absence of site specific data. For a life-cycle cost of $32,179 for a point-in-space approach, the benefits to be gained range from a high of $1,723,775 for Chicago O'Hare International to a low of $25,218 for Anchorage International. This represents a benefit to cost ratio of 53.6 to 1 and 0.78 to 1, respectively.

At some airports, point-in-space approaches are not operationally suitable. As an alternative, rotorcraft intercept points and reduced IFR rotorcraft-to-aircraft separation could be implemented at high-activity airports. Figures 25 and 26 present the respective life-

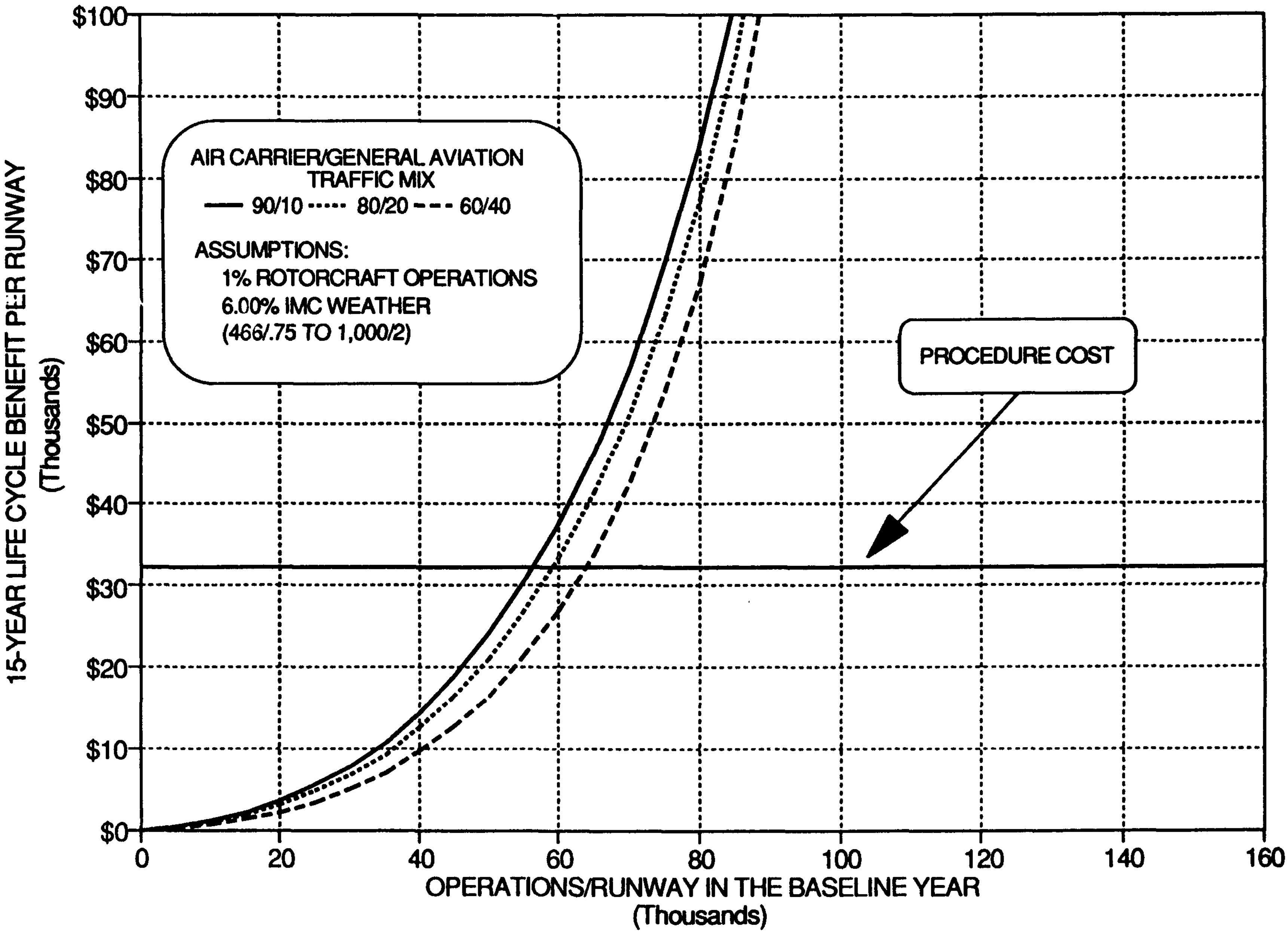


FIGURE 24 BENEFIT FOR ROTORCRAFT POINT-IN-SPACE APPROACH PROCEDURE

TABLE 10
PROCEDURAL BENEFITS
15-Year Life-Cycle Benefits in 1990 Dollars

AIRPORT	STATE	PERCENT ROTORCRAFT*	POINT-IN-SPACE APPROACH	CLOSER INTERCEPT	REDUCED SEPARATION
ANCHORAGE INTERNATIONAL	AK	2.73	25,218	5,055	3,643
SAN DIEGO LINBERGH INT'L	CA	1.07	61,420	10,663	6,884
LOS ANGELES INTERNATIONAL	CA	0.60	495,934	92,101	59,479
OAKLAND INTERNATIONAL	CA	11.72	116,961	15,506	15,506
ONTARIO INTERNATIONAL	CA	2.26	60,137	11,292	8,135
DENVER STAPLETON INTERNATIONAL	CO	0.72	57,091	11,901	7,683
WASHINGTON NATIONAL	DC	2.41	288,835	49,641	35,817
ATLANTA INTERNATIONAL	GA	0.31	250,706	54,295	35,053
CHICAGO OHARE INTERNATIONAL**	IL	0.20	1,723,775	287,793	186,027
INDIANAPOLIS INTERNATIONAL	IN	3.44	92,639	17,191	12,392
NEW ORLEANS MOISANT INT'L	LA	1.97	25,750	4,580	3,300
BOSTON LOGAN INTERNATIONAL	MA	1.15	172,358	35,213	22,743
BALTIMORE-WASHINGTON INT'L	MD	2.29	78,345	15,574	11,223
WAYNE DETROIT METROPOLITAN	MI	1.43	321,516	63,669	41,145
SAINT LOUIS INTERNATIONAL	MO	0.86	186,911	35,357	22,836
NEWARK INTERNATIONAL	NJ	0.48	121,261	23,405	15,109
KENNEDY INTERNATIONAL	NY	0.66	50,949	11,225	7,244
LAGUARDIA INTERNATIONAL	NY	0.61	526,393	118,862	76,836
PHILADELPHIA INTERNATIONAL	PA	1.93	256,430	49,084	35,397
GREATER PITTSBURG INT'L	PA	0.62	111,577	21,949	14,169
HOUSTON INTERNATIONAL	TX	0.22	163,757	28,907	18,661
DALLAS-FORT WORTH INT'L	TX	1.19	104,737	19,937	12,874
SALT LAKE CITY INTERNATIONAL	UT	3.14	77,954	16,502	11,903
SEATTLE TACOMA INTERNATIONAL	WA	0.42	54,681	11,052	7,134

* Percent of total airport operations based on an assumption that IFR rotorcraft operations equals 6 percent of IFR GA operations.

** Growth rate capped at 95 percent of ultimate capacity.

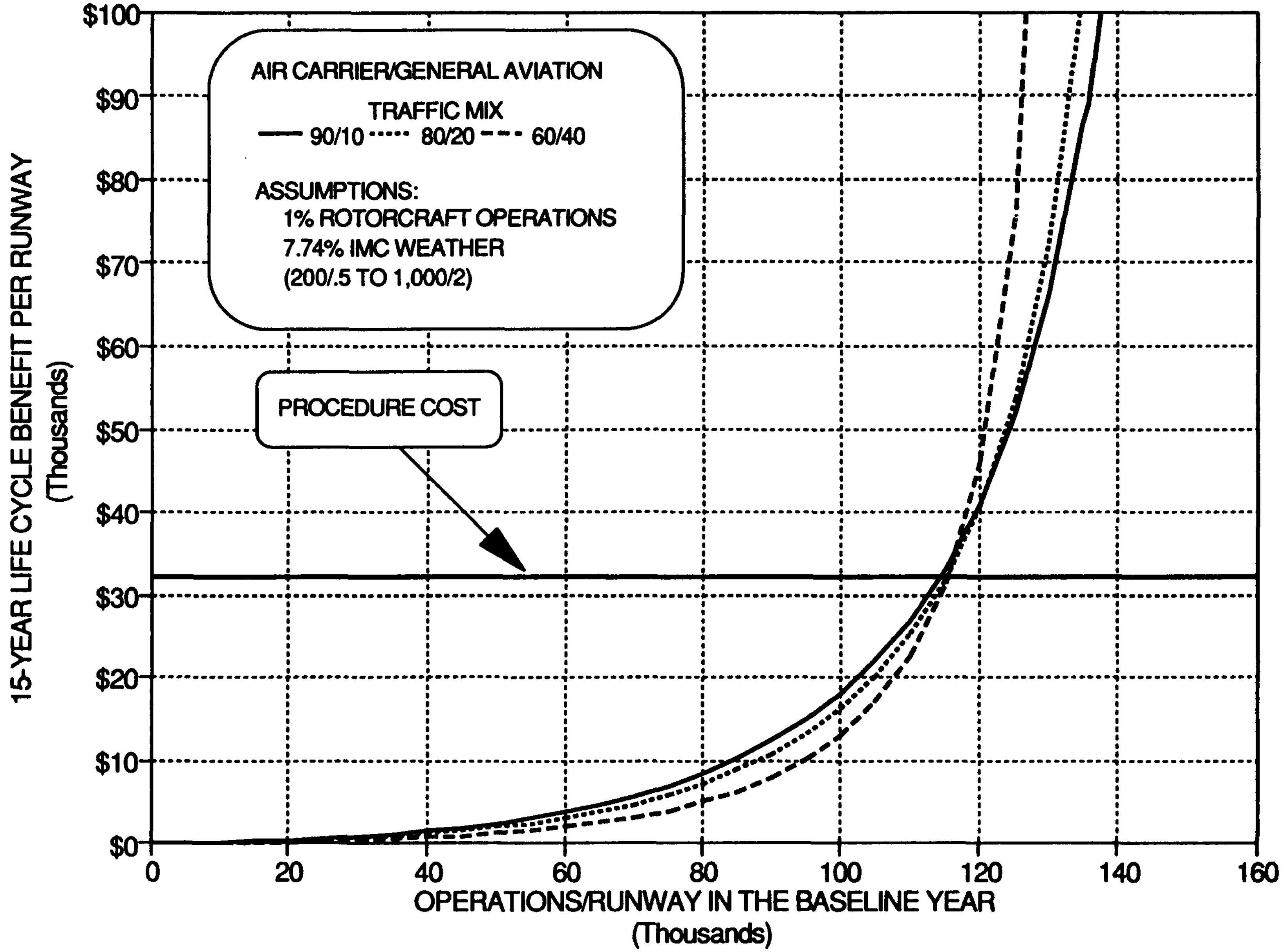


FIGURE 25 BENEFIT FOR ROTORCRAFT INTERCEPT POINT PROCEDURE

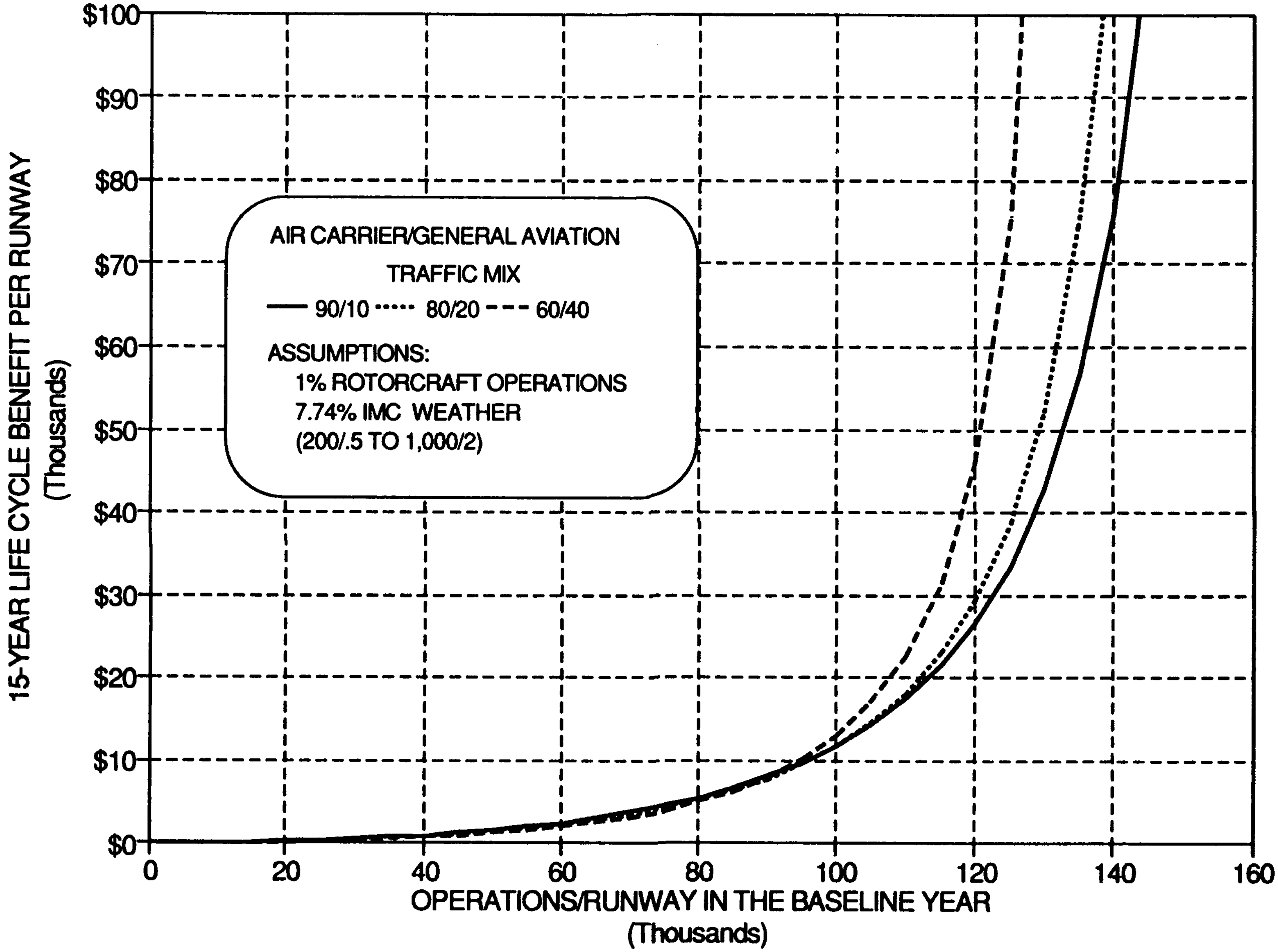


FIGURE 26 BENEFIT FOR REDUCED ROTORCRAFT SEPARATION PROCEDURE

cycle benefits per rotorcraft instrument approach for each of the procedural improvements.

Figures 24 through 26 assume that 1 percent of all operations at the airport are performed by rotorcraft and that average national aviation weather minimums apply. Benefits for the point-in-space procedure apply when the weather is between point-in-space minimums (assumed to be 466 feet ceiling and 3/4 mile visibility) and VFR minimums (assumed to be 1,000 feet ceiling and 2 miles visibility). Since the rotorcraft are landing on the IFR runway, benefits for the rotorcraft intercept point procedure and the reduced separation procedure are assumed to apply for weather between precision instrument approach minimums (assumed to be 200 feet and 1/2 mile visibility) and VFR minimums.

The benefit of reducing the distance from the intercept point to the runway for rotorcraft at a major airport is derived from reducing delays to both rotorcraft and fixed-wing aircraft. This benefit is dependent on the percentage of time the weather is IMC, for the same reasons given for the point-in-space approach benefit. Likewise, the growth rates assumed are the same. The benefits to be gained range from a high of $287,793 for Chicago O'Hare International to a low of $4,580 for New Orleans Moisant Airport. This procedure is clearly worth implementing at some of the larger, congested airports. However, based on benefit/cost analyses, it is questionable whether New Orleans and Anchorage have enough traffic to justify implementing this procedure. The cost of implementing this procedure is assumed to be the same as that of developing a new instrument approach procedure.

The benefit of reducing the separation between a rotorcraft and an in-trail fixed-wing aircraft at a major airport is derived from reducing delays for both aircraft. This benefit is directly proportional to the percentage of time the weather is IMC for the same reasons given for the point-in-space approach benefit. Likewise, the growth rates assumed are the same. The benefits to be gained range from a high of $186,027 for Chicago O'Hare International Airport to a low of $3,300 for New Orleans Moisant Airport. The cost of implementing this procedure is the cost of the research and development effort required to justify changing the separation criteria. These costs are unknown at this time. Once the policy is changed, no further annual costs are incurred.

7.0 CONCLUSIONS

The National Airspace System adequately satisfies most rotorcraft user needs in the en route environment. The major exception to this is the en route structure in the Gulf of Mexico. The NAS is also becoming increasingly more capable with the incorporation of new technologies and procedures.

Rotorcraft user needs that are not being satisfied arise when rotorcraft operate in congested terminal airspace shared with many fixed-wing aircraft or operate in airspace where limited ATC services are available. Solutions to unanswered rotorcraft operational needs are addressed below.

Communications. For the foreseeable future, the remote communication facility (RCF) will remain the only viable communications system between air traffic control and smaller aircraft (including rotorcraft). Despite their limitations, RCFs provide sufficient communication coverages to fulfill rotorcraft user needs in most areas.

In terminal areas, additional RCFs may be needed to support remote heliports when sufficient IFR operations are performed. However, there was insufficient rotorcraft operational data to support these establishments.

In the Gulf of Mexico, the FAA has identified a near-term requirement for additional RCFs to fill low altitude communications voids. Future offshore rotorcraft mission requirements for communications will also arise when rotorcraft support offshore rigs located beyond 200 miles offshore. It is unknown what regulatory restrictions will be imposed if communications are unavailable to rotorcraft flying far offshore.

Navigation. The combination of VOR/DME, LORAN-C, and eventually GPS adequately meet rotorcraft user needs during VFR and IFR en route flight. LORAN-C and GPS, if approved for instrument approaches on a broad basis, also offer the potential to satisfy rotorcraft operational needs for low cost instrument approaches to remote and mountainous areas.

In benefit/cost terms, many heliports supporting IFR-capable rotorcraft could justify instrument approach procedure establishment. Issues and disadvantages of instrument approaches must also be considered. Public-use instrument approaches require control zones, which can adversely affect VFR/SVFR operations. At private heliports, owners must pay the costs involved in establishing and maintaining the approach. Also, the FAA will require additional resources to support the expected influx of instrument approach procedure requests.

Surveillance. Rotorcraft activity by itself is insufficient to warrant the installation of additional surveillance radars. Based on FAA methodology, the benefits derived from terminal radar are primarily attributed to their ability to reduce sequencing delays in terminal areas. Currently, the number of IFR operations at heliports does not reach adequate levels to justify this improvement. Much larger rotorcraft (at least 30 to 40 passengers) and much greater operations rates (20 to 25 operations in peak hours) are required to justify investment in a terminal radar to support heliport operations.

The FAA's benefit/cost methodology for the installation of a terminal radar includes benefits from satellite airports that receive qualified radar service. Applying this methodology, future heliports could be a contributor to the overall benefit from surveillance radar. However, no airport was identified where the number of annual operations from an existing satellite heliport would support establishment of a new terminal radar.

In the Gulf of Mexico, IFR rotorcraft activity is sufficient to justify improving offshore surveillance. The FAA is considering LOFF as an inexpensive solution, but progress has been slow and a number of ATC operational and safety issues remain unresolved.

The more conventional solution of installing an air route surveillance radar with an air traffic control radar beacon system has also been proposed. Three radar systems properly situated would provide adequate coverage to sufficiently alleviate sequencing delays.

Assuming 5-mile radar separation and 10-mile LOFF separation, LOFF would deliver a higher benefit/cost ratio and a larger benefit minus cost value. It is expected that a GPS-based system would offer benefits similar to LOFF.

Procedural Improvements. Rotorcraft SIDs, STARs, and instrument approaches have the potential to increase the economic viability of commercial rotorcraft. These procedures could reduce or eliminate rotorcraft delays during instrument approaches and departures by permitting vertical flight aircraft to make approaches and departures that minimize interference with fixed-wing aircraft.

Rotorcraft operational needs are not significant enough to justify major changes in the NAS or to incorporate revolutionary technologies or ATC procedures. Improvements to the NAS to satisfy existing and future rotorcraft operational needs would best be accomplished by making refinements in existing systems and programs and taking advantage of technologies like LORAN-C and satellite services. The procedures identified in this report can both satisfy rotorcraft user needs and increase the capacity of the NAS.

Benefit/Cost Methodology. One of the significant benefits to the nation provided by rotorcraft is in lives saved by air ambulance helicopters and in services provided in disaster relief efforts. Of those patients transported by air ambulance helicopters between hospitals, medical research indicates that approximately 2.25 percent would have died had they traveled by some other mode of transportation.

Hospital Heliports. Hospital heliports provide tremendous benefits to the nation in terms of providing EMS helicopters with rapid access to hospitals. Using these heliports, helicopter EMS services save lives and reduce morbidity (faster recovery from injury, decrease in long term disability, etc.). These benefits could be increased and the safety of EMS operations could be enhanced through the installation of nonprecision approaches at hospital heliports. This analysis indicates that, at many hospital heliports, the benefit/cost ratio of a nonprecision approach is very large. In a number of cases, it is larger than 1,000 to 1. Unfortunately, Federal funding is not currently available to provide such services. The FAA's interpretation of the will of Congress is that hospital heliports are always private facilities and therefore not eligible for Federal funding. This FAA interpretation is not likely to change without Congressional action on this issue.

8.0 RECOMMENDATIONS

1. FAA and rotorcraft industry representatives should jointly pursue a method to develop a data base of rotorcraft operations that is acceptable to the FAA in order to justify rotorcraft improvements to the NAS. The emphasis should be on operations counts at public and high-activity heliports/airports.

2. By supporting research and development of LORAN-C and GPS, the FAA is making instrument approaches more amenable to rotorcraft user requirements. The FAA should next enable instrument approaches to be more easily implemented at heliports, especially those that support the EMS rotorcraft mission. Instrument approaches to hospital heliports would allow increased use of rotorcraft and would contribute to a nationwide reduction in patient morbidity and mortality. This can be accomplished by expediting the certification of LORAN-C and GPS instrument approaches and equipment and by streamlining the procedures for establishing an instrument approach procedure.

3. The FAA should modify its benefit/cost methodology in order to consider the benefit of lives that could be saved by the expansion of helicopter and fixed-wing air ambulances.

4. The FAA should consider establishing a special category for hospital heliports to allow use of Federal funds to finance improvements to facilities and instrument approaches. The FAA would have to use the word "public" in the new category. The Heliport Technical Planning Committee of the Helicopter Association International (HAI) is considering this issue. Possible terms such as "public service" rather than "public use" are being considered. Under such a classification and with a justified operator's request, the FAA should develop and maintain instrument approaches to these heliports.

5. The FAA should implement a demonstration project to develop SIDs, STARs, and rotorcraft instrument approaches to one or more high activity airports. This program should be completely documented and serve as a model for other airports. One airport that would serve this purpose is Los Angeles International Airport. This airport currently experiences high numbers of delays, has IMC weather 11 percent of the time, and an operator has expressed interest in providing an IFR rotorcraft commuter service.

6. The rotorcraft community should continue to request LORAN-C and/or GPS nonprecision instrument approaches and should identify specific locations and their associated priorities to the FAA.

7. The FAA should further analyze the advantages and disadvantages of installing instrument approaches to hospital heliports. Several specific sites should be chosen and all issues addressed in detailed site-specific studies. After several candidate sites have

been analyzed, and a baseline of activity documented, a pilot IFR EMS operation should be implemented to gain experience and decisively demonstrate the benefit of IFR EMS heliports.

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ADL	Aeronautical Data Link
ADS	Automatic Dependent Surveillance
AGL	Above Ground Level
AIA	Aerospace Industries Association
ARA	Airborne Radar Approach
ARSR	Air Route Surveillance Radar
ARTCC	Air Route Traffic Control Center
ASR	Airport Surveillance Radar
ATC	Air Traffic Control
ATCRBS	Air Traffic Control Radar Beacon System
AWOS	Automated Weather Observing System
CFR	Code of Federal Regulations
CIP	Capital Investment Plan
CNS	Communications, Navigation, Surveillance
CWP	Central Weather Processor
DEC	Digital Equipment Corporation
DH	Decision Height
DME	Distance Measuring Equipment
DRMS	Distance Root Mean Square
EMS	Emergency Medical Service
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulation
FLIR	Forward-Looking Infrared Radar
FSAS	Flight Service Automation System
FSS	Flight Service Station
GPS	Global Positioning Satellite
HALS	Heliport Approach Lighting Systems
HF	High Frequency
HSAC	Helicopter Safety Advisory Conference
HUD	Heads-up Display
IFR	Instrument Flight Rules
ILS	Instrument Landing System
IMC	Instrument Meteorological Conditions
LADARS	Laser Radars
LLLTV	Low-Light Level Television
LOFF	LORAN-C Offshore Flight Following
LORAN-C	Long Range Navigation
MDA	Minimum Decision Altitude
MEA	Minimum En Route Altitude
MLS	Microwave Landing System
MMWR	Millimeter-Wave Radar
MSL	Mean Sea Level
NAS	National Airspace System
NDB	Nondirectional Beacon
NMI	Nautical Miles
OMB	Office of Management and Budget
OSAP	Offshore Standard Approach Procedure
PCRM	Parallel/Converging Runway Monitor
PRM	Parallel Runway Monitor
RCAG	Remote Communications Air/Ground Facility

RCF	Remote Communications Facility
RCO	Remote Communications Outlet
RNAV	Area Navigation
RTR	Remote Transmitter/Receiver
RVR	Runway Visual Range
SAR	Search and Rescue
SFAR	Special Federal Aviation Regulation
SIAP	Standard Instrument Approach Procedure
SID	Standard Instrument Departure
STAR	Standard Terminal Arrival Route
SVFR	Special Visual Flight Rules
TCAS	Terminal Collision Avoidance System
TEC	Tower En Route Control
TERPS	Terminal Instrument Procedures
TRACON	Terminal Radar Approach Control
UHF	Ultra High Frequency
VFR	Visual Flight Rules
VHF	Very High Frequency
VMC	Visual Meteorological Conditions
VOR	VHF Omnidirection Range
VSTOL	Vertical/Short Takeoff and Landing

APPENDIX A
APPLICABLE FEDERAL AVIATION REGULATIONS

Federal Aviation Regulations make allowances for rotorcraft capabilities and limitations. An understanding of "rotorcraft regulations" is essential to addressing the community's needs. In particular, the following regulations taken from the Federal Aviation Regulations revised January 1, 1992 were considered relevant to this investigation.

-91.119 (d) Minimum safe altitudes; general. *Helicopters may be operated at less than the minimums prescribed in paragraph (b) or (c) of this section if the operation is conducted without hazard to persons or property on the surface. In addition, each person operating a helicopter shall comply with routes or altitudes specifically prescribed for helicopters by the Administrator.*

-91.127 (a) Operating on or in the vicinity of an airport: General Rules. *(b) Each person operating an aircraft to or from an airport without an operating control tower shall -(2) In the case of a helicopter approaching to land, avoid the flow of fixed-wing aircraft.*

-91.129 (e) Operation at airports with operating control towers - Approaches. *When approaching to land at an airport with an operating control tower, each pilot of -(2) A helicopter, shall avoid the flow of fixed-wing aircraft.*

-91.151(b) Fuel requirements for flight under VFR conditions. *No person may begin a flight in a rotorcraft under VFR conditions unless (considering wind and forecast weather conditions) there is enough fuel to fly to the first point of intended landing and, assuming normal cruising speed, to fly after that for at least 20 minutes* [Note: As compared to fixed-wing requirements of 30 minutes for day flights and 45 minutes for night flights].

-91.155 Basic VFR weather minimums. ...*(b) Inapplicability. Notwithstanding the provisions of paragraph (a) of this section, the following operations may be conducted outside of controlled airspace below 1,200 feet above the surface: (1) Helicopter. A helicopter may be operated clear of clouds if operated at a speed that allows the pilot adequate opportunity to see any air traffic or obstruction in time to avoid a collision.*

-91.157 Special VFR weather minimums. ...*(c) No person may operate an aircraft (other than a helicopter) in a control zone under VFR unless flight visibility is at least one statute mile.*

(d) No person may takeoff or land an aircraft (other than a helicopter) at any airport in a control zone under VFR-...

(e) No person may operate an aircraft (other than a helicopter) in a control zone under the special weather minimums of this section between sunset and sunrise ...

-91.175 Takeoff and landing under IFR....*(c) Operation below DH or MDA. Where a DH or MDA is applicable, no pilot may operate an aircraft, except a military aircraft of the United States, at any airport below the authorized MDA or continue an approach below the authorized DH unless - (1) The aircraft is continuously in a position from which a descent to a landing on the intended runway can be made at a normal rate of descent using normal maneuvers, and for operations conducted under part 121 or part 135 unless that descent rate will allow touchdown to occur within the touchdown zone of the runway of intended landing; (2) The flight visibility is not less than the visibility prescribed in the standard instrument approach being used; and...(f) Civil airport takeoff minimums. Unless otherwise authorized by the Administrator, no pilot operating an aircraft under parts 121, 125, 127, 129, or 135 of this chapter may take off from a civil airport under IFR unless weather conditions are at or above the weather minimum for IFR takeoff prescribed for that airport under part 97 of this chapter. If takeoff minimums are not prescribed under part 97 of this chapter for a particular airport, the following minimums apply to takeoffs under IFR for aircraft operating under those parts:...(3) for helicopters - 1/2 statute mile visibility.*

-93.113 Control zones within which special VFR weather minimums are not authorized *No person may operate a fixed-wing aircraft under the special VFR weather minimums prescribed in "paragraph" 91.107 of this chapter within the following control zones:....*

-97.3 Symbols and terms used in procedures (d-1)...*Helicopters may also use other procedures prescribed in Subpart C of this part and may use the Category A minimum descent altitude (MDA) or decision height (DH). The required visibility minimum may be reduced to one-half the published visibility minimum for Category A aircraft, but in no case may it be reduced to less than one-quarter mile or 1,200 feet RVR.*

-127- CERTIFICATION AND OPERATIONS OF SCHEDULED AIR CARRIERS WITH HELICOPTERS SFAR 38-2 has postponed Part 127 requirements for rotorcraft operators. Part 127 will likely be replaced with part 119.

-135.181 Performance requirements: Aircraft operated over-the-top or in IFR conditions. (b) ...*multiengine helicopters carrying passengers offshore may conduct such operations in over-the-top or in IFR conditions at a weight that will allow the helicopter to climb at least 50 feet per minute with the critical engine inoperative when operating at the MEA of the route or 1,500 feet MSL, whichever is higher....*

(c)(2)(i) Without regard to paragraph (a) of this section - (2) If the latest weather reports or forecasts, or any combination of them, indicate that the weather along the planned route allows flight under VFR under the ceiling (if a ceiling exists) beginning at a point no more than 15 minutes flying time at normal cruise speed from the departure airport, a person may (i) Take off from the departure airport in IFR conditions and fly in IFR conditions to a point no more

than 15 minutes flying time at normal cruise speed from that airport;... While this regulation does not specifically target rotorcraft, many rotorcraft operators have cited the latter part of this regulation as a significant limitation.

-135.183 Performance Requirements: Land aircraft operated over water. *No person may operate a land aircraft carrying passengers over water unless-(d) It is a helicopter equipped with helicopter flotation devices.*

-135.203 VFR: Minimum Altitudes except when necessary for takeoff and landing, no person may operate under VFR -...(b) *A helicopter over a congested area at an altitude less than 300 feet above the surface.*

-135.205 VFR: Visibility requirements (b) *No person may operate a helicopter under VFR in uncontrolled airspace at an altitude of 1,200 feet or less above the surface or in control zones unless the visibility is at least-(1) During the day-1/2 mile; or (2) At night-1 mile.*

-135.207 VFR: Helicopter surface reference requirements. *No person may operate a helicopter under VFR unless that person has visual surface reference or, at night, visual surface light reference, sufficient to safely control the helicopter.*

-135.223 IFR: Alternate airport requirements except as provided in paragraph (b) of this section, no person may operate an aircraft in IFR conditions unless it carries enough fuel to - (3) *Fly after that for 45 minutes at normal cruising speed or, for helicopters, fly after that for 30 minutes at normal cruising speed.*

-135.227 Icing conditions: Operating limitations (c) *No person may fly a helicopter under IFR into known or forecast icing conditions unless it has been type certificated and appropriately equipped for operations in icing conditions.*

-135.229 Airport Requirements. *No pilot of an aircraft carrying passengers at night may take off from, or land on, an airport unless-2) The limits of the area to be used for landing of takeoff are clearly shown - ...(ii)For helicopters, by boundary of runway marker lights or reflective material.*

United States Standard for Terminal Instrument Procedures (TERPS) Chapter 11 Helicopter Procedures. *... These criteria are based on the premise that helicopters are approach Category A aircraft with special maneuvering characteristics. The intent, therefore, is to provide relief from those portions of other TERPS chapters which are more restrictive than the criteria specified herein. An underlying premise of this report is that many rotorcraft user requirements are different than those of their fixed-wing counterparts. This section describes the unique characteristics of rotorcraft, the FARs that specifically affect rotorcraft operations and pertinent rotorcraft*

mission information. It is these three factors that warrant rotorcraft receiving special consideration in many FAA analysis.

SFAR No. 29-4-Limited IFR Operations of Rotorcraft *... an operator of a rotorcraft that is not otherwise certificated for IFR operations may conduct limited IFR operation in the rotorcraft when-...* (This regulation is currently not being used).

APPENDIX B
RATIONALE FOR CALCULATING TERMINAL COMMUNICATIONS AND TERMINAL SURVEILLANCE BENEFITS

B.1 INTRODUCTION

The rationale for calculating terminal communications and terminal surveillance benefits is based on terminal capacity relationships. The development of benefits for each of these ATC improvements is similar in concept but quite different in terms of the terminal capacities involved. Because the concepts are quite similar, only the terminal communications concepts will be discussed in detail. The terminal surveillance benefits will then be discussed with regard to the differences in terminal capacities and the levels of benefits.

B.2 TERMINAL COMMUNICATIONS BENEFITS

Appendix C of reference 14 presents discussions of IFR delay computations. These discussions will be summarized herein. Without terminal communications, helicopter operations (sum of takeoffs and landings) to/from a heliport are limited to approximately six operations per hour. Because helicopters arrive at and depart from the heliport in a random manner, the theoretical capacity of six operations per hour cannot be achieved in actual practice. Based on work in appendix E, a theoretical model of the delay encountered by all aircraft was developed. This delay is represented by the following equation:

$$\text{Delay (minutes)} = \frac{60*(\text{Operations per hr/Theoretical Capacity})^2}{(1-\text{Operations per hr/Theoretical Capacity})} \quad \text{(Equation B-1)}$$

Table 2 in section 3.3 (reprinted here as table B-1 for convenience) presents the expected delay and disruption costs for various rotorcraft missions. For this analysis, the business mission will be used as an example. Delay costs for the business mission are $322.70 per hour or $5.38 per minute of delay. In this example, delays are assumed to occur during the four peak operating hours at a heliport during the five weekdays (references 31 and 32). Also, 50 weeks of operation per year at the heliport are assumed. Therefore, as represented by equation 1, delays are most likely to occur at the heliport during 1,000 hours of peak operations per year. The delays represented by equation B-1 only occur when the helicopters are operated under instrument flight rules (IFR).

As an example, assuming an operations rate of 4 operations per hour and a theoretical capacity of 6 operations per hour, equation 1 produces a total delay value for all helicopters of 80 minutes per hour of peak hour operation when the helicopters are operating under IFR. At a cost of $5.38 per minute of delay, each hour of heliport operation during a peak hour of IFR operations costs the operators $430 in delay costs. Helicopter IFR conditions are assumed to occur in the weather minimums range between 800:1 (800 feet ceiling and 1 mile visibility) and 466:0.75. Based on the U.S. national average, minimums within this range occur about 2.95 percent of the time. When

TABLE B-1 ROTORCRAFT ECONOMIC COSTS (1990 DOLLARS)

A	B	C	D	E	F	G
MISSION	VARIABLE OPERATING COSTS PER HOUR	AVERAGE NUMBER OF PASSENGER/ OCCUPANTS	VALUE OF OCCUPANTS TIME	DIVERTED PASSENGER HANDLING EXPENSE	TOTAL DELAY COSTS PER HOUR	TOTAL COST PER DISRUPTION
EMS	$155.30	3.50	$125.55	$78.06	$594.73	$804.71
OFFSHORE	155.30	4.50	83.70	78.06	531.95	702.83
AIR TAXI	217.80	3.30	87.43	78.06	506.32	559.32
BUSINESS	155.30	2.00	83.70	78.06	322.70	331.35
CORP/EXEC	155.30	3.30	83.70	78.06	431.51	524.52
COMMUTER	217.80	4.80	83.70	78.06	619.56	761.15

Source: Reference 14.

multiplied by 1,000 hours of annual heliport operations during peak hours, the number of helicopter IFR peak hours during a year is 29.5 hours. Multiplying these IFR peak hours by the delay cost per peak hour yields a total annual cost to the operators of $12,700. This cost as a function of peak hour operations rates is shown as curve 1 in figure B-1. Note that curve 1 rapidly increases in value as the operations rate approaches the theoretical capacity of six operations per hour.

As costs increase rapidly due to delays in operations, helicopter operators are faced with an economic question of whether it is more prudent to: 1) operate with rapidly increasing costs, 2) cancel the flight, 3) hold the flight at the originating heliport, or 4) divert to another nearby heliport or airport location if one is available. Thus the intended flight is disrupted. Disruption costs are represented in figure B-1 by curve 2. Annual disruption costs are calculated by multiplying the disruption cost per operation from table B-1, column G, $331.35, by the operations rate per hour times 29.5 hours of annual disruptions during helicopter IFR conditions. This produces a linear curve in figure B-1 with a slope of $9,775 per helicopter operation per hour. For instance, at 10 business helicopter operations per hour, the total annual disruption cost is $97,750.

In figure B-1, it is apparent that at approximately 5.2 operations per hour, delay costs due to a lack of communications equals the cost associated with disrupting the flight through cancellation, diversion, or holding the flight on the ground at the originating airport or heliport. When operations exceed this crossover point at 5.2 operations per hour, prudent operators driven by economic factors will choose to disrupt their flights rather than accept skyrocketing delay costs. Therefore, the true cost of not having terminal communications is represented by the minimum of curve 1 or curve 2.

In a similar manner, the delay costs associated with operations using terminal communications are developed. As developed in appendix C of reference 14, the theoretical capacity of a heliport terminal area with terminal communications is approximately 18 operations per hour. The same delay equation B-1 is applicable to this situation as well. Delay costs are calculated in the same manner as the case where there are no terminal communications; the only difference is in the theoretical capacity of 18 operations per hour instead of 6 operations per hour. The resulting delay costs with terminal communications is represented in figure B-1 by curve 3.

In a manner analogous to the case with no terminal communications, there is a crossover point as the operations rate approaches 17 operations per hour. Beyond this crossover point, the cost associated with disrupting helicopter flights is less than continuing to operate with increasing delay costs. Again, prudent operators driven by economic factors would choose to cancel, divert, or hold flights rather than operate with airborne delays. The delay costs associated

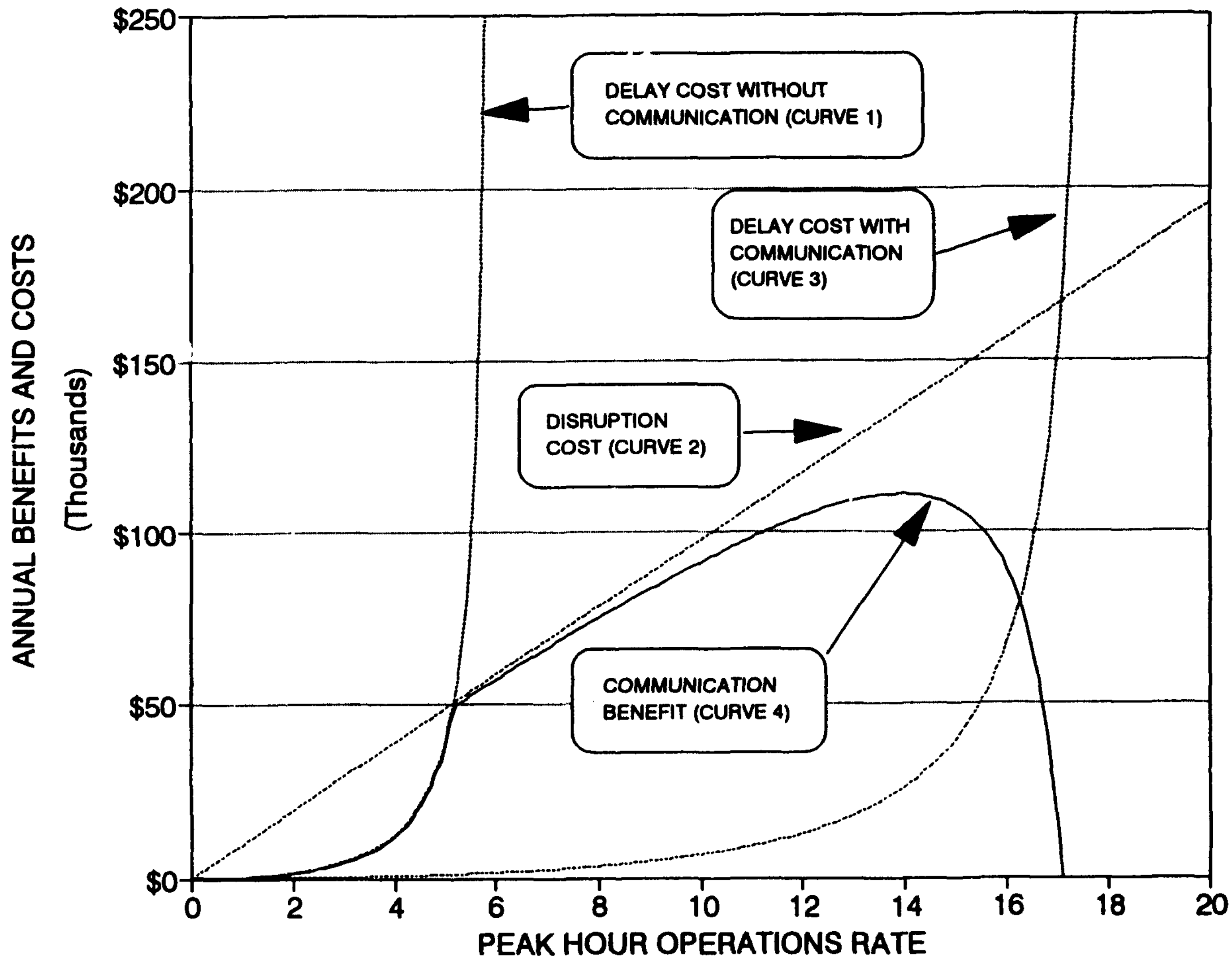


FIGURE B-1 TERMINAL COMMUNICATION ANALYSIS - ROTORCRAFT BUSINESS OPERATIONS

with operations with terminal communications is the minimum of curve 3 or curve 2.

The annual benefits associated with the use of terminal communications is the difference between the delay cost associated with operations without terminal communications less the delay cost of operations with terminal communications. Referring to figure B-1, this is expressed as:

Annual Benefits = Minimum (curve 1, 2) - Minimum (curve 3, 2) (Equation B-2)

The annual benefits are identified as curve 4 in figure B-1. Note that for points greater than the crossover point of 17 operations per hour, the benefits go to zero because helicopter operators will choose to disrupt flights for both the "with communications" and "without communications" cases.

B.3 TERMINAL COMMUNICATIONS LIFE-CYCLE BENEFITS

Estimates of life-cycle benefits for establishing terminal communications at a heliport are shown in figure B-2 for the mission categories shown in table B-1. No life-cycle benefits are shown for the EMS mission, because these flights often are granted expeditious handling by ATC. Therefore, this mission category would usually not suffer the ATC handling delays experienced by the other five mission categories.

Life-cycle benefits are calculated by multiplying the annual IFR delay benefits by the 15-year life-cycle benefit factor 7.977. This factor is calculated by the following sum:

$$\text{Benefit Factor} = \text{Sum}_{n=1 \text{ to } 15}\ 1 / 1.1^{(n-0.5)} = 7.977 \qquad \text{(Equation B-3)}$$

This factor applies if the expected annual benefits are equal. If they are not approximately equal, then each annual benefit must be multiplied by the discount factor for year n as identified in the equation above.

B.4 TERMINAL COMMUNICATIONS BENEFIT/COST RATIO

The benefit/cost ratio is calculated by dividing the curves shown in figure B-2 by the 15-year life-cycle cost of the communications facility. In reference 14, appendix B, this cost is identified as $413,181. These curves are shown in figure B-3. When peak hour operations exceed 4.5 to 5.0 operations per hour, benefits exceed costs. Based on an estimated 30 percent of operations occuring during the peak hours, 4.5 to 5.0 peak hour operations represents approximately 14,000 to 17,000 annual operations.

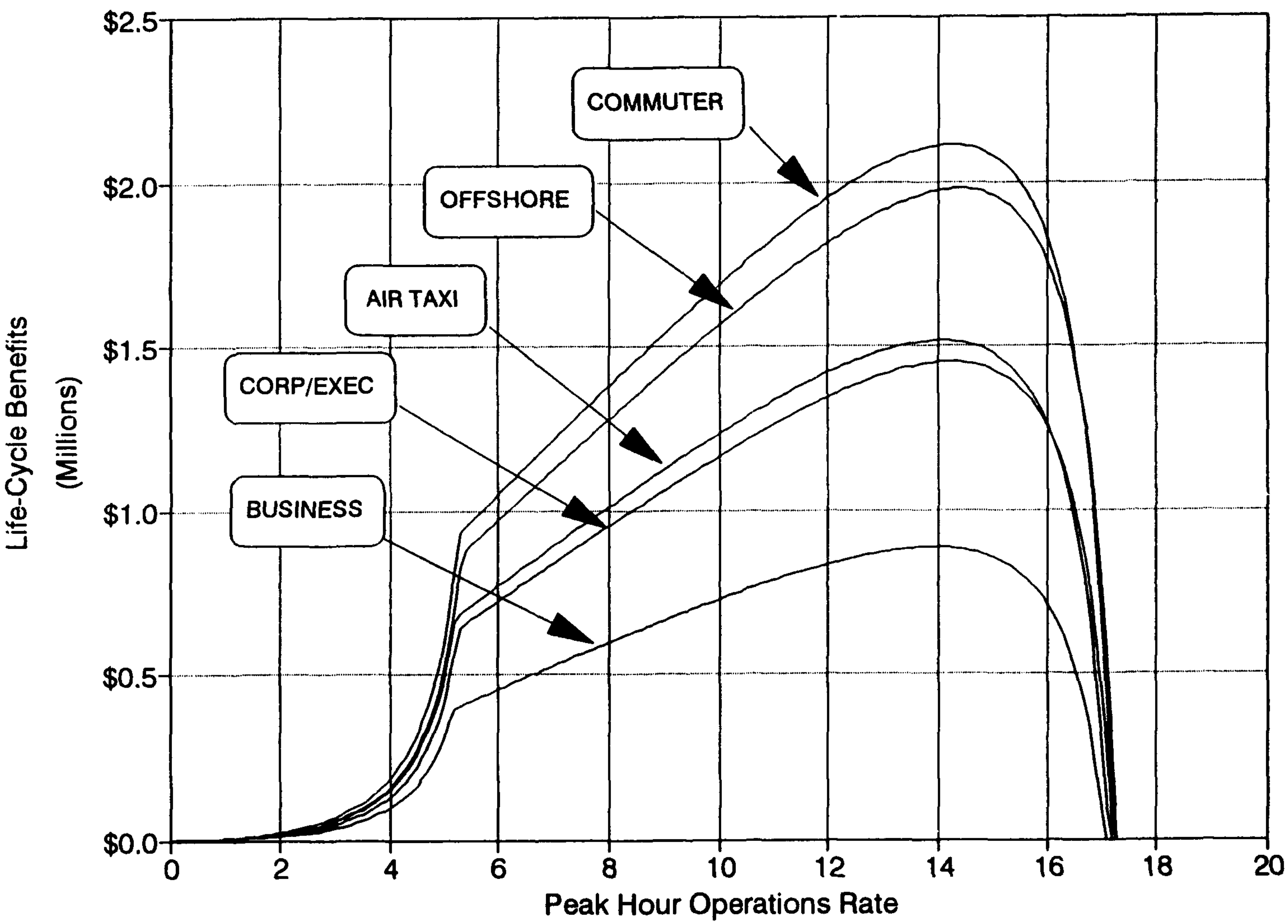


FIGURE B-2 TERMINAL COMMUNICATIONS LIFE-CYCLE BENEFITS FOR ROTORCRAFT OPERATIONS

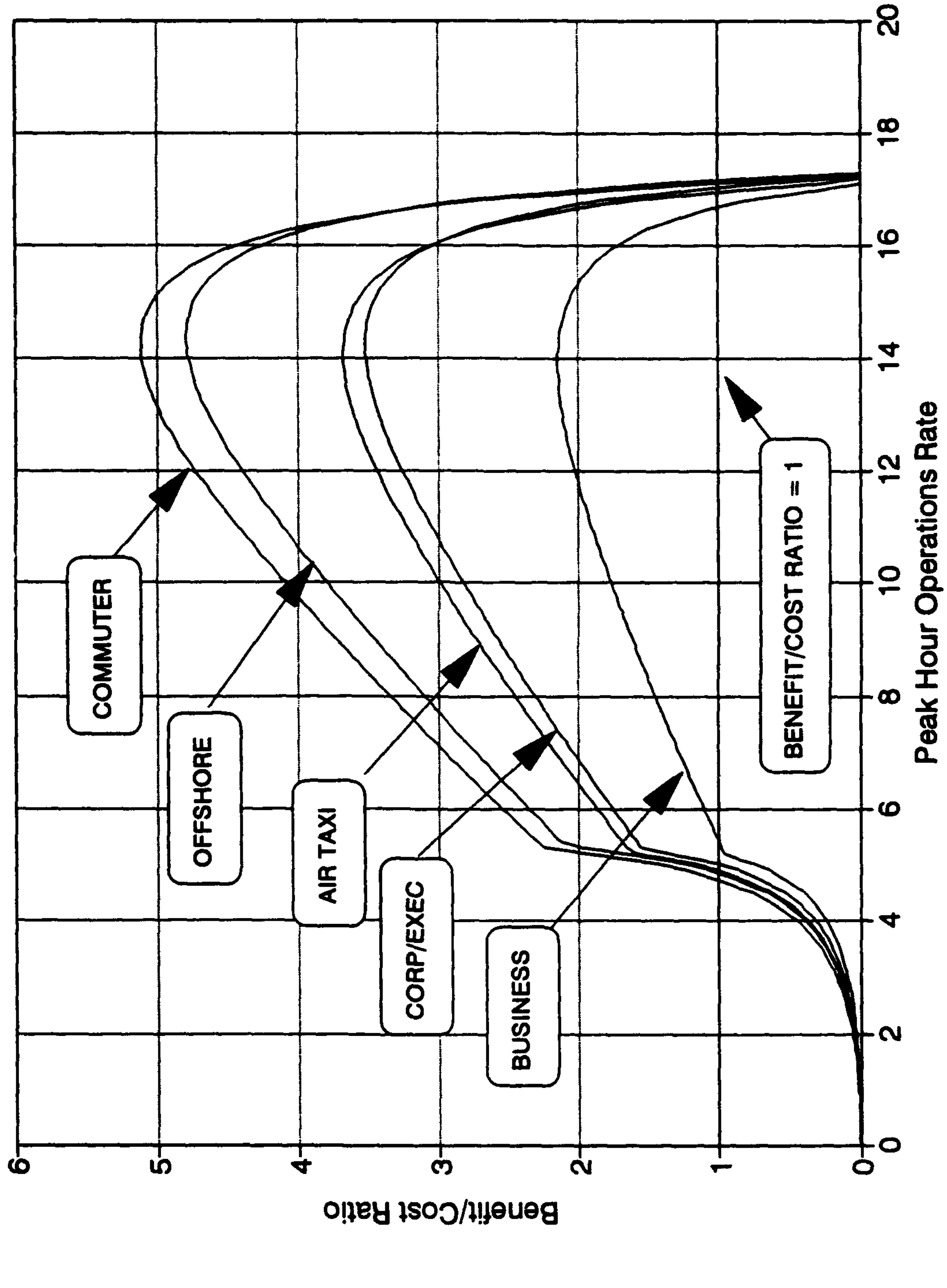


FIGURE B-3 TERMINAL COMMUNICATIONS BENEFIT/COST RATIO FOR ROTORCRAFT OPERATIONS

B.5 TERMINAL SURVEILLANCE BENEFITS

Terminal surveillance benefits are calculated in a manner similar to the calculation of terminal communications benefits. The only differences are the theoretical capacities used in equation B-1. For the case where there is no terminal surveillance, the theoretical capacity is assumed to be 18 rotorcraft operations per hour, the value that applies to the terminal communications case. With terminal surveillance, appendix C of reference 14 develops a theoretical capacity of 30 operations per hour. Annual benefits are determined by subtracting the delay costs without surveillance from the delay costs with surveillance.

Figure B-4 shows the 15-year life-cycle benefits for the mission categories shown in table B-1, except the EMS mission. Again, because EMS missions often receive expedited ATC handling, they will not experience the delays represented by equation B-1. Note that for each mission category, the maximum surveillance benefit is roughly 1.8 times the maximum communications benefit shown in figure B-2.

B.6 TERMINAL SURVEILLANCE BENEFIT/COST RATIO

Terminal surveillance life-cycle costs are based on the cost of an ASR-9 terminal radar. Appendix F shows the average cost of an ASR-9 in 1990 dollars to be approximately $16 million. Terminal surveillance benefit/cost ratios are calculated by dividing the benefits shown in figure B-4 by $16 million. The results, presented in figure B-5, show that none of the mission categories shown in table B-1 have sufficient benefits to justify establishment of an ASR-9 based on operations at the heliport only. The maximum ratio achieved is about 0.24 for the commuter mission with about 25 peak hour IFR operations. Based on the estimated 30 percent of operations occuring in peak hours, this represents about 83,000 annual operations. The commuter operation represented by the costs shown in table B-1 represents modest size helicopters with a capacity of about 10 passengers with a 50 percent load factor. Larger commuter helicopters carrying more passengers (for example, a capacity of 30 to 40 passengers or more) could conceivably achieve a benefit/cost ratio greater than unity at a very busy heliport.

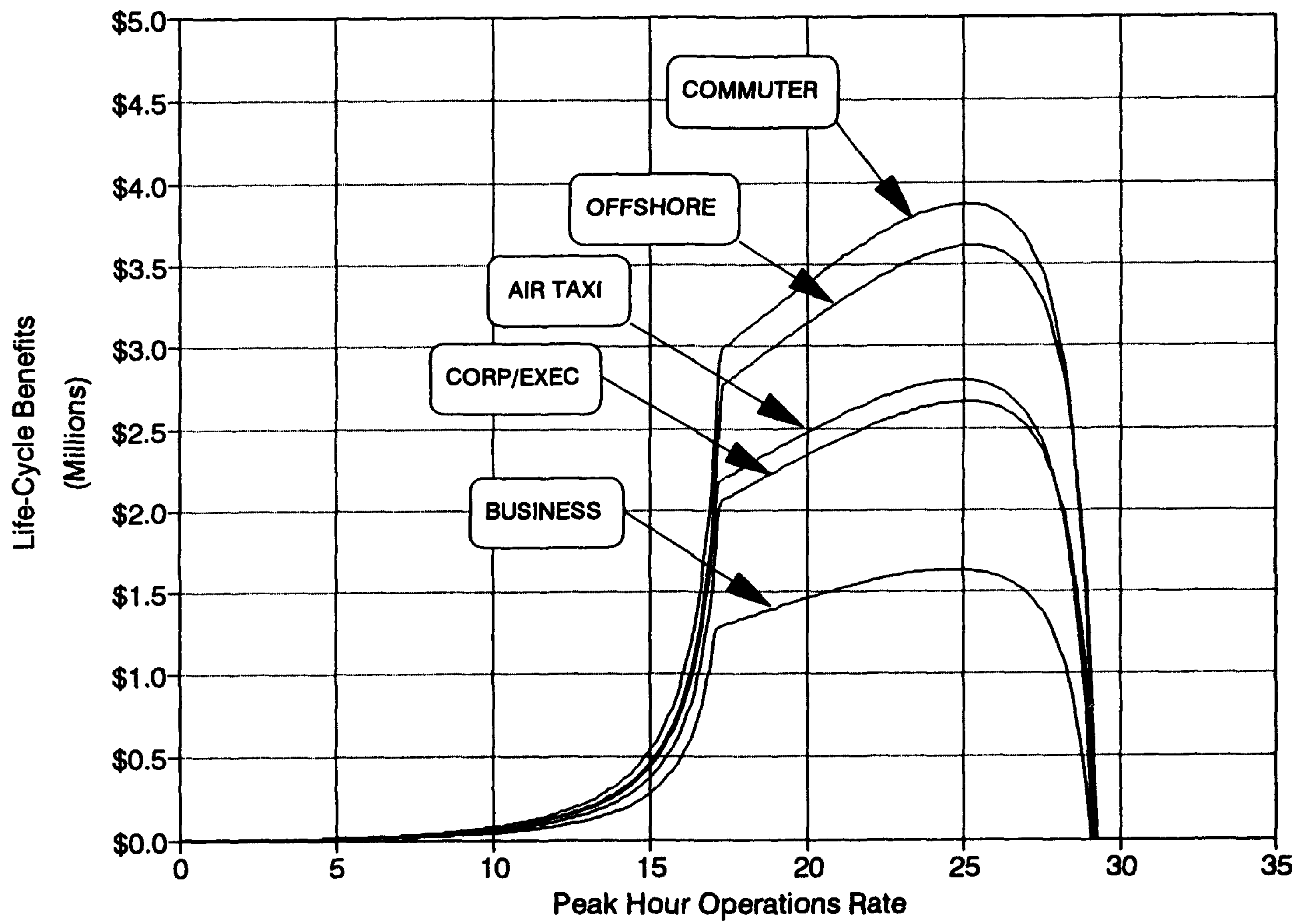


FIGURE B-4 TERMINAL SURVEILLANCE LIFE-CYCLE BENEFITS
FOR ROTORCRAFT OPERATIONS

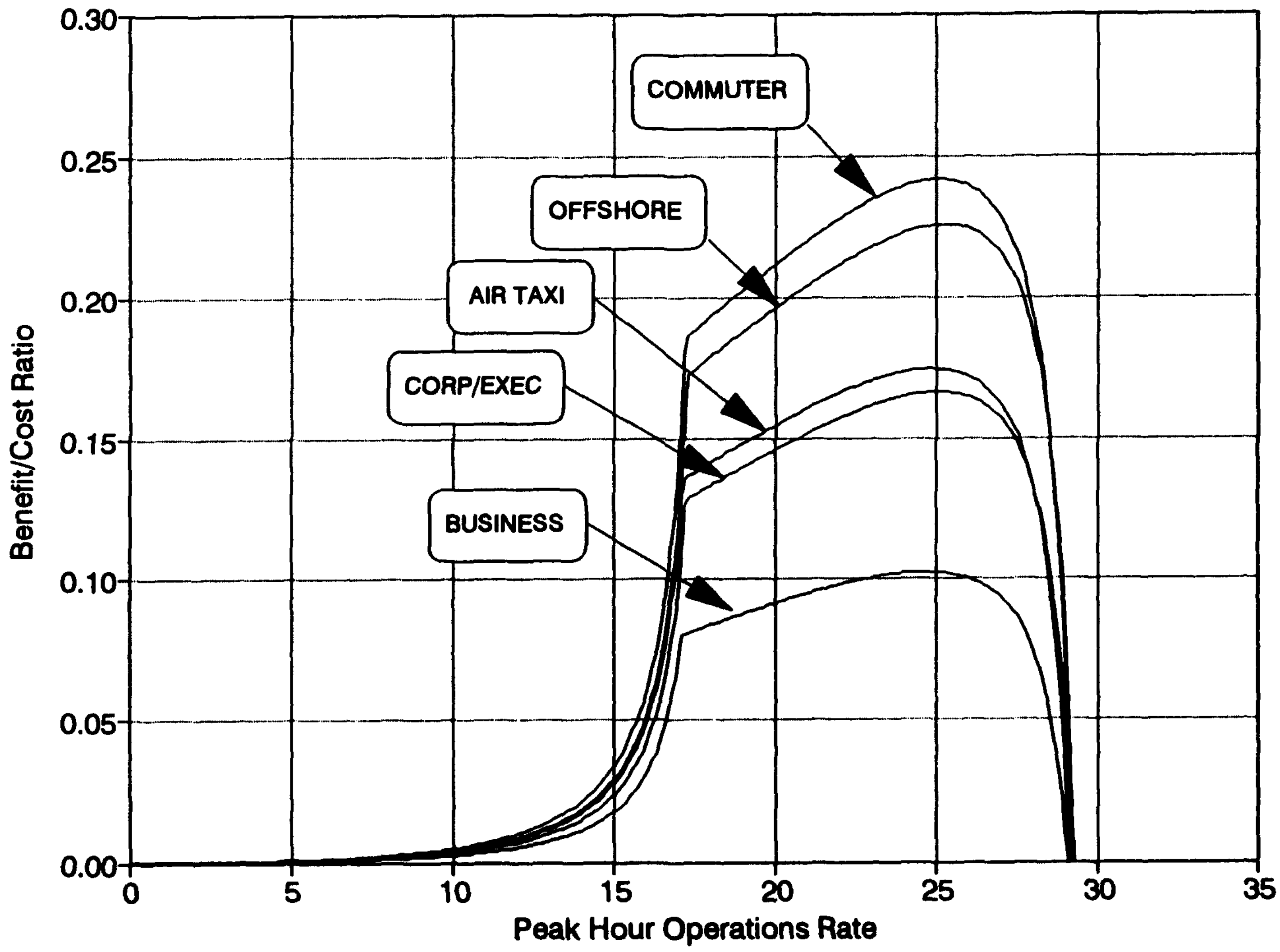


FIGURE B-5 TERMINAL SURVEILLANCE BENEFIT/COST RATIO FOR ROTORCRAFT OPERATIONS

APPENDIX C
EXAMPLE CALCULATIONS OF BENEFITS

This appendix provides example calculations of the benefits for terminal communications, figure C-1; terminal surveillance, figure C-2; en route surveillance, figure C-3 and tables C-1 and C-2; nonprecision approaches to non-EMS and EMS helipads, respectively, figures C-4 and C-5; point-in-space approaches, figure C-6; rotorcraft intercept points, figure C-7; and reduced separation on approaches, figure C-8. All of the calculations refer back to the methodologies developed and explained in the second interim report (reference 14) denoted as DS-89/10 where referenced. Additionally, the point-in-space approaches, the rotorcraft intercept point procedures, and the reduced separation on approaches refer to appendix E of this document.

Note that most of the examples in this appendix assume a zero percent growth rate. This assumption was made only for the reason of computational and presentation simplicity. With zero percent growth rate, the annual computation of benefits are identical for each of the 15 years used in the life-cycle benefit/cost analysis. Therefore, discounted 15-year benefits can be calculated by simply multiplying 1 year's benefit by the factor of 7.977*. However, to demonstrate the full 15-year methodology, the benefits for providing LORAN-C dependent surveillance in the Gulf of Mexico are presented in table C-1, and the benefits for providing ASR-9 surveillance in the Gulf of Mexico are presented in table C-2.

(*Note: In recent months, OMB has lowered the discount rate from 10 to 7 percent (see reference 32) and OST has directed that the value of life used in DOT benefit/cost analysis should be increased from $1.5 million to $2.5 million (see reference 33). The calculations in this document were done with the old values. Thus, they will tend to understate net benefits. As an example, with the change in the discount rate, the "15-year factor" mentioned above changes from 7.9773 to 9.4213. Thus, we recommend that you use the revised values in any future analyses.)

The examples used in this appendix are intended to illustrate the mechanics in applying the methodology. The values selected and the results obtained are intended for illustration purposes only.

The following list of abbreviations is used in all examples to conserve space.

AGL = above ground level	MIN = minutes
FT = feet	OPS = operations
HR = hr	VFR = visual flight rules
IFR = instrument flight rules	YR = year

Assumptions:	
Probability of the weather being below 800 feet ceiling and 1 mile visibility:	6.0%
Probability of the weather being below 466 feet ceiling and 3/4 mile visibility:	3.2%
Peak hours per year:	1,000 peak hrs/year
Annual operations:	17,000 ops/year
Annual growth rate	0% annual growth
Initial approach fix altitude:	3,000 feet AGL
Mission is offshore oil support	
Delay costs per hour for offshore	$531.95/hr (DS-89/10, p. 131)
Step 1 Calculations (DS-89/10, p. 135)	
Percent of time weather is between 466 ft and 3/4 mile and 1,000 ft and 1 mile.	6.0% - 3.2% = 2.8%
Annual IFR Operations:	17,000 * 2.8% = 476 IFR ops/year
IFR peak hours per year:	(1,000 hours) * 2.8% = 28 IFR peak hrs/yr
Step 2 Calculations	
Determine rotorcraft IFR operations per peak hour:	476 rotorcraft IFR ops/yr * 30% in peak hr = 143 rotorcraft IFR peak hr ops/yr
Step 3 Calculations	
Determine average number of IFR operations per peak hour:	(143 rotorcraft IFR peak hr ops/yr)/(28 IFR peak hrs/yr) = 5.1 IFR ops per peak hr
Determine delay reduction per hour:	Enter g equation 4 (DS-89/10, p. 135) with 5.1 IFR peak ops per hr and 10 miles spacing yields 282 min of delay reduction per hr
Step 4 Calculations	
Determine delay reduction per year:	(282 minutes of delay reduction/hr)* (28 IFR peak hrs/yr)*(1 hr/60 min) = 132 hrs of delay reduction per yr
Determine annual dollar benefit:	(132 hrs of delay reduction/yr) *($531.95/delay hr) = $70,217/yr

FIGURE C-1 TERMINAL COMMUNICATIONS - BENEFIT 4T (DS-89/10, p. 132)

Step 5 Calculations	
Determine 15-year life cycle benefit:	Multiply $70,217 per yr by 7.977 multiplier (DS-89/10, p. 152) to convert constant annual dollars to a 15-yr life cycle to yield $560,121 15-yr life cycle benefit.
Determine benefit/cost ratio:	From appendix B (DS-89/10, B-1), the cost of a RCAG is $413,181. The benefit/cost ratio is 1.36.

FIGURE C-1 TERMINAL COMMUNICATIONS - BENEFIT 4T (DS-89/10, p. 132) (Continued)

Assumptions:	
Probability of the weather being below 800 feet ceiling and 1 mile visibility:	6.0%
Probability of the weather being below 466 feet ceiling and 3/4 mile visibility:	3.2%
Peak hours per year:	1,000 peak hrs
Total delay costs per hour:	$550 per hr (average for all missions)
Rotorcraft annual operations:	47,000 ops per yr
Annual growth rate for all operations:	0% annual growth
Step 1 Calculations (DS-89/10, p. 138)	
Percent of time weather is between 466 ft and 3/4 mile and 800 ft and 1 mile:	6.0% - 3.2% = 2.8%
Annual IFR operations:	(47,000 ops)(2.8%) = 1,316 IFR ops/yr
IFR peak hours per year:	(1,000 peak hrs) * 2.8% = 28 IFR peak hrs/yr
Step 2 Calculations	
Determine rotorcraft IFR operations per peak hour:	1,316 IFR ops/yr * 30% in peak hr = 395 rotorcraft IFR peak hr ops/yr
Step 3 Calculations	
Determine average number of IFR peak hour rotorcraft operations per hour:	(395 rotorcraft IFR peak hr ops/yr)/(28 IFR peak hrs/yr) = 14.1 IFR ops/peak hr
Determine delay reduction per hour:	Enter equation 10 (DS-89/10, p. 139) with 14.1 IFR ops per peak hr. Calculate 145 min of delay reduction per peak hr.
Step 4 Calculations	
Determine delay reduction per year with surveillance:	(145 min of delay reduction/peak hr)* (28 IFR peak hrs/yr) = 4,060 min of delay reduction per yr
Determine savings/year with surveillance:	(4,060 min of delay reduction/yr) * (1 hr/60 min)*($550/hr) = $37,217/yr

FIGURE C-2 TERMINAL SURVEILLANCE - BENEFIT 6T (DS-89/10, p. 137)

Step 5 Calculations	
Determine 15-year life cycle benefit:	Multiply $37,217 per yr by 7.977 multiplier (DS-89/10, p. 152) to convert constant annual dollars to a 15-yr life cycle to yield $296,877 15-year life cycle benefit. If "IFR rotorcraft operations/peak hour" exceed 17.2, repeat steps 1 through 5 to capture "disruption costs. Add 15-yr delay costs to 15-yr disruption costs as shown in table 15 (DS-89/10, p. 143).
Determine benefit/cost ratio:	From appendix F, the cost of an ASR-9 is $16.0 million. Obviously the benefit/cost ratio (0.02) is unfavorable for the heliport alone. However, if there are other airports or heliports in the coverage area of the radar, the benefits from each site can be combined into an overall benefit.

FIGURE C-2 TERMINAL SURVEILLANCE - BENEFIT 6T (DS-89/10, p. 137) (Continued)

Assumptions:	
Mission:	Commuter in the Gulf of Mexico
Annual Growth Rate:	0% Annual growth
Probability of the weather being below 800 feet ceiling and 1 mile visibility:	6.08%
Probability of the weather being below 250 feet ceiling and 3/4 mile visibility:	1.69%
Surveillance Method:	LORAN-C offshore flight following which will provide 22.5 minutes of delay reduction per sortie. (Radar surveillance providing 32.5 minutes of delay reduction per sortie is analyzed in table C-2.)
Analysis (DS-89/10, p. 142)	
Determine number of IFR days per year:	6.08% - 1.69% = 4.39% IFR weather (0.0439 IFR weather)*(250 weekdays/yr) = 10.98 IFR days/yr.
Determine number of flights affected per year:	(0.9 operational rotorcraft/total rotorcraft)*(115 IFR rotorcraft)*(6 sorties/rotorcraft/day)*(10.98 IFR days/yr) = 6,819 sorties/yr
Determine delay costs:	From table 12 (DS-89/10, p. 131), the delay costs for the for the offshore mission are $531.95/hr
Determine annual dollar benefit:	(6,819 sorties/yr)*(22.5 min of delay reduction/sortie)*($531.95/hr)* (1 hr/60 min) = $1.36 million/yr (DS-89/10, p. 144). (For radar surveillance use 32.5 minutes of delay reduction/sortie. Note that delay per sortie would increase annually if growth is assumed.)
Determine 15-year life cycle benefit:	Multiply 1.36 million dollars per yr by 7.977 multiplier (DS-89/10, p. 152) to convert constant annual dollars to a 15-year life cycle to yield 10.8 million dollars 15-year cycle benefit. Note that calculations in tables C-1 and C-2 reflect larger benefits because growth in the number of annual operations is considered.
Determine benefit/cost ratio:	From appendix B (DS-89/10, p. B-3), the 15-year life-cycle cost of a LOFF system is 1.65 million dollars. The benefit/cost ratio is 6.57.

FIGURE C-3 EN ROUTE SURVEILLANCE IN THE GULF OF MEXICO - BENEFIT 6E (DS-89/10, p. 142)

TABLE C-1 BENEFITS FOR ADDING LOFF ADS IN THE GULF OF MEXICO

Surveillance Method	LOFF	
Mission	Offshore	
Percent IMC Weather	4.39%	
Flying Days per Year	250	Weekdays
IFR Days per Year	10.98	
Sorties/day	6	
Delay Cost per Hour	$531.95	
Delay Reduction per Sortie (initial year)	22.5	minutes
Percent Aircraft Operational	90%	

Cum Years	Year	Fleet Growth Rate	IFR Fleet	IFR Days/ Year	Sorties Delayed/ Year	Delay Reduction per Sortie (minutes)	Annual Delay Cost Savings ($ M)	Discount Factor	Discounted Benefits ($ M)	Cum Benefits ($ M)
1	1992	2.7%	115.0	10.98	6,819	22.5	$1.36	0.953	$1.30	$1.30
2	1993	2.7%	118.1	10.98	6,999	23.1	$1.43	0.867	$1.24	$2.54
3	1994	2.7%	121.3	10.98	7,188	23.7	$1.51	0.788	$1.19	$3.73
4	1995	2.7%	124.6	10.98	7,383	24.4	$1.60	0.716	$1.14	$4.87
5	1996	3.7%	129.2	10.98	7,656	25.3	$1.72	0.651	$1.12	$5.99
6	1997	3.7%	134.0	10.98	7,939	26.2	$1.84	0.592	$1.09	$7.08
7	1998	3.7%	138.9	10.98	8,233	27.2	$1.98	0.538	$1.07	$8.15
8	1999	3.7%	144.1	10.98	8,537	28.2	$2.13	0.489	$1.04	$9.20
9	2000	3.7%	149.4	10.98	8,853	29.2	$2.29	0.445	$1.02	$10.22
10	2001	3.7%	154.9	10.98	9,181	30.3	$2.47	0.404	$1.00	$11.21
11	2002	3.7%	160.6	10.98	9,520	31.4	$2.65	0.368	$0.98	$12.19
12	2003	3.7%	166.6	10.98	9,873	32.6	$2.85	0.334	$0.95	$13.14
13	2004	3.7%	172.7	10.98	10,238	33.8	$3.07	0.304	$0.93	$14.07
14	2005	3.7%	179.1	10.98	10,617	35.0	$3.30	0.276	$0.91	$14.98
15	2006	3.7%	185.8	10.98	11,010	36.3	$3.55	0.251	$0.89	$15.88

TABLE C-2 BENEFITS FOR ADDING ASR-9 SURVEILLANCE IN THE GULF OF MEXICO

Surveillance Method	ASR-9	
Mission	Offshore	
Percent IMC Weather	4.39%	
Flying Days per Year	250	Weekdays
IFR Days per Year	10.98	
Sorties/day	6	
Delay Cost per Hour	$531.95	
Delay Reduction per Sortie (initial year)	32.5	minutes
Percent Aircraft Operational	90%	

Cum Years	Year	Fleet Growth Rate	IFR Fleet	IFR Days/ Year	Sorties Delayed/ Year	Delay Reduction per Sortie (minutes)	Annual Delay Cost Savings ($ M)	Discount Factor	Discounted Benefits ($ M)	Cum Benefits ($ M)
1	1992	2.7%	115.0	10.98	6,819	32.5	$1.96	0.953	$1.87	$1.87
2	1993	2.7%	118.1	10.98	6,999	33.4	$2.07	0.867	$1.80	$3.67
3	1994	2.7%	121.3	10.98	7,188	34.3	$2.18	0.788	$1.72	$5.39
4	1995	2.7%	124.6	10.98	7,383	35.2	$2.30	0.716	$1.65	$7.04
5	1996	3.7%	129.2	10.98	7,656	36.5	$2.48	0.651	$1.61	$8.65
6	1997	3.7%	134.0	10.98	7,939	37.9	$2.66	0.592	$1.58	$10.23
7	1998	3.7%	138.9	10.98	8,233	39.3	$2.87	0.538	$1.54	$11.77
8	1999	3.7%	144.1	10.98	8,537	40.7	$3.08	0.489	$1.51	$13.28
9	2000	3.7%	149.4	10.98	8,853	42.2	$3.31	0.445	$1.47	$14.76
10	2001	3.7%	154.9	10.98	9,181	43.8	$3.56	0.404	$1.44	$16.20
11	2002	3.7%	160.6	10.98	9,520	45.4	$3.83	0.368	$1.41	$17.61
12	2003	3.7%	166.6	10.98	9,873	47.1	$4.12	0.334	$1.38	$18.98
13	2004	3.7%	172.7	10.98	10,238	48.8	$4.43	0.304	$1.35	$20.33
14	2005	3.7%	179.1	10.98	10,617	50.6	$4.77	0.276	$1.32	$21.64
15	2006	3.7%	185.8	10.98	11,010	52.5	$5.12	0.251	$1.29	$22.93

Assumptions:	
Probability of the weather being above/below 800 feet ceiling and 1 mile visibility:	94.0%/6.0%
Probability of the weather being below 466 feet ceiling and 3/4 mile visibility:	3.2%
Annual VFR rotorcraft approaches:	3,000
Percentage of IFR-certificated rotorcraft:	50%
Mission type:	Offshore
Annual growth rate:	0%
Step 1 Calculations (DS-89/10, p. 145)	
Percentage of time weather is between 800 feet and 1 mile and 466 feet and 3/4 mile:	% weather = 6.0 - 3.2 = 2.8%
Calculate number of operations that receive benefits (appendix D, equation 2):	3,000 * 50% IFR equipped * 2.8%/94% = 44.7 IFR approaches/year
Step 2 Calculations	
From table 12 (DS-89/10, p. 131) read cost per disruption for offshore mission:	$702.83/disruption
Step 3 Calculations	
Determine annual dollar benefit:	(44.7 IFR rotorcraft approaches/yr) * ($703/disruption) = $31,424/yr
Determine 15-year life-cycle benefit:	Multiply $31,424/yr by 7.977 multiplier (DS-89/10, p. 152) to convert constant annual dollars to a 15-year life cycle to yield $250,670 15-year life-cycle benefit.
Determine benefit/cost ratio:	From appendix F, the cost of a LORAN-C nonprecision approach is $32,179 in 1990 dollars. The benefit/cost ratio is 7.8.

FIGURE C-4 NONPRECISION APPROACHES (NON-EMS) - BENEFIT 8 (DS-89/10, p. 145)

Assumptions:	
Probability of the weather being above/below 800 feet ceiling and 1 mile visibility:	94.0%/6.0%
Probability of the weather being below 466 feet ceiling and 3/4 mile visibility:	3.2%
Rural population of:	250,000 people
Number of hospital helipads:	6
Percentage of IFR-capable helicopters/ crews:	100%

See DS-89/10 (appendix D and section 8.3.4) for background on the values used for: 1) transports/population/year, 2) % interhospital transports, 3) % trauma patients, 4) % mortality reduction, and 5) the dollar value of a human life.

Step 1 Calculations (DS-89/10, p. 145)	
Percentage of time weather is between 800 feet and 1 mile, and 466 feet and 3/4 mile:	% IFR weather = 6.0 - 3.2 = 2.8%
Calculate IFR operations factor (appendix D, equation 2):	100% * 2.8% / 94% = 2.98%
Step 2 Calculations	
Determine the annual number of patients transported per year:	(250,000 people)*(275 transports/ 100,000 people/yr) = 688 transports/yr
Step 3 Calculations	
Determine annual dollar benefit:	(688 transports/yr)*(75% interhospital transport)*(40% trauma patient)*(7.5% mortality reduction)*(2.98% IFR ops factor)*($1.5 million per life saved) = $692.000/year
Determine 15-year life cycle benefit:	Multiply $692,000 per yr by 7.977 multiplier (DS-89/10, p. 152) to convert constant annual dollars to a 15-year life cycle to yield $5.52 million
Find life cycle benefit per helipad:	($5.52 million/6 helipads) = $920,000 15-year life cycle benefit per helipad
Determine benefit/cost ratio:	From appendix B (DS-89/10, p. B-2), the cost of a LORAN-C nonprecision approach is $32,179. The benefit/cost ratio is 28.6 for each of 6 helipads.

FIGURE C-5 NONPRECISION APPROACHES TO HOSPITAL HELIPORTS - BENEFIT 8 (DS-89/10, p. 145)

Assumptions:	
Probability of the weather being below 1,000 feet ceiling and 1 mile visibility:	6.0%
Probability of the weather being below 466 feet ceiling and 3/4 mile visibility:	3.2%
Peak hours per year:	1,252 hours (DS-89/10, p. 148)
Fixed-wing annual instrument operations:	120,000 operations per year
Helicopter annual instrument operations:	3,000 operations per year
Annual growth rate for all operations:	0% annual growth
Ratio of air transport to general aviation operations:	80% air transport/20% general aviation
Step 1 Calculations (DS-89/10, p. 148)	
Percent of time weather is between 466 ft and 3/4 mile and 1,000 ft and 1 mile:	6.0% - 3.2% = 2.8%
IFR peak hours per year:	(1,252 hours)*2.8% = 35 IFR peak hours/yr
Step 2 Calculations	
From table 16 (DS-89/10, p. 149), find fixed-wing IFR peak hour operations:	Entering table 16 with 120,000 annual instrument operations yields 54 IFR peak hour ops without rotorcraft.
Determine rotorcraft IFR ops/peak hour:	3,000 rcft ops/yr * 30% in peak hr/ 1,252 peak hr = 0.72 rcft IFR peak hr ops
Determine rotorcraft IFR approaches/ peak hour:	0.72 IFR ops/peak hr * 50% = .36 IFR approaches/peak hour
Step 3 Calculations	
Determine fixed-wing delay with no rotorcraft in the approach que from equation E-1 in appendix E:	From table E-1, the ultimate capacity of a runway with an 80/20 mix is 77.32. Applying equation E-1 gives: $(54/77.32)^2/(1-54/77.32)$ = 1.62 hrs of delay per peak hour.
Determine equivalent operations per IFR peak hour with rotorcraft in the approach que from equation E-1:	Using a touchdown ratio of 1.78 from table E-3 yields 54 fixed-wing IFR ops/peak hr plus 0.36 rcft IFR peak hr approaches times 1.78 touchdown ratio equals 54.64 ops per peak hr with rotorcraft.

FIGURE C-6 POINT-IN-SPACE APPROACH - BENEFIT 9 (DS-89/10, p. 147)

Determine fixed-wing plus rotorcraft delay from equation E-1 (appendix E):	From table E-1 the ultimate capacity is still 77.32. Applying equation E-1 gives $(54.64/77.32)^2/(1-54.64/77.32)$ = 1.70 hrs of delay per peak hr.
Step 4 Calculations	
Determine delay reduction with use of point-in-space approach for rotorcraft:	1.70 hours of delay with rotorcraft minus 1.62 hours of delay without rotorcraft yields 0.08 hours of delay reduction per IFR peak hr.
Step 5 Calculations	
Determine annual IFR peak hour delay reduction:	0.08 hours delay reduction/hr times 35 IFR peak hrs/yr equals 2.8 hrs of annual delay reduction.
Determine annual dollar benefit:	From table 19 (DS-89/10, p. 152) for an 80/20 aircraft mix obtain $4,539 delay cost per hr. Multiply 2.8 hrs savings times $4,539 to yield $12,709 per yr.
Step 6 Calculations	
Determine 15-year life cycle benefit:	Multiply $12,709 per yr by 7.977 multiplier (DS-89/10, p. 152) to convert constant annual dollars to a 15-year life cycle to yield $101,381 15-year life-cycle benefit.
Determine benefit/cost ratio:	From appendix F, the cost of a point-in-space approach is assumed to be about the same as a LORAN-C nonprecision approach, which is $32,179. The benefit/cost ratio is 3.2.

FIGURE C-6 POINT-IN-SPACE APPROACH - BENEFIT 9 (DS-89/10, p. 147) (Continued)

Assumptions:	
Probability of the weather being below 1,000 feet ceiling and 1 mile visibility:	6.0%
Probability of the weather being below 466 feet ceiling and 3/4 mile visibility:	3.2%
Peak hours per year:	1,252 hours
Fixed-wing annual instrument operations:	120,000 operations per year
Helicopter annual instrument operations:	3,000 operations per year
Annual growth rate for all operations:	0% annual growth
Ratio of air transport to general aviation operations:	90% air transport/10% general aviation
Step 1 Calculations (DS-89/10, p. 156)	
Percent of time weather is between 466 ft and 3/4 mile and 1,000 ft and 1 mile:	6.0% - 3.2% = 2.8%
IFR peak hours per year:	(1,252 hrs)*2.8% = 35 IFR peak hours/yr
Step 2 Calculations	
From table 16 (DS-89/10, p. 149), find fixed-wing IFR peak hour operations:	Entering table 16 with 120,000 annual instrument operations yields 54 IFR peak hour ops without rotorcraft.
Determine rotorcraft IFR ops/peak hour:	3,000 rcft ops/yr*30% in peak hr/ 1,252 peak hr = 0.72 rcft IFR peak hr ops
Determine rotorcraft IFR approaches/ peak hour:	0.72 IFR ops/peak hr * 50% = 0.36 IFR approaches/peak hr
Step 3 Calculations	
Determine delay without a rotorcraft intercept point from equation E-1 in appendix E.	From table E-1, the ultimate capacity of a runway with a 90/10 mix is 80.21. Using a touchdown ratio of 2.05 from table E-3, yields 54 fixed-wing IFR ops/peak hr plus 0.36 rcft IFR peak hr ops times 2.05 touchdown ratio equals 54.74 ops per peak hr without a rcft intercept point. Applying equation E-1 gives: $(54.74/80.21)^2/(1-54.74/80.21)$ = 1.467 hrs of delay per peak hr.

FIGURE C-7 ROTORCRAFT INTERCEPT POINT AT A CONGESTED AIRPORT - BENEFIT 10 (DS-89/10, p. 155)

Determine delay with a rotorcraft intercept point from equation E-1:	Using a touchdown ratio of 1.74 from table E-4 yields 54 fixed-wing IFR ops/peak hr plus 0.36 rcft IFR peak hr approaches times 1.74 touchdown ratio equals 54.63 ops per peak hr with a rotorcraft intercept point. Applying equation E-1 gives: $(54.63/80.21)^2/(1-54.63/80.21) = 1.455$ hrs of delay per peak hr.
Step 4 Calculations	
Determine delay reduction with use of rotorcraft intercept point:	1.467 hrs of delay without rotorcraft intercept point minus 1.455 hrs of delay without rotorcraft intercept point yields 0.012 hrs of delay reduction per IFR peak hr.
Step 5 Calculations	
Determine annual IFR peak hour delay reduction:	0.012 hrs delay reduction/hr times 35 IFR peak hrs/yr equals 0.42 hrs of annual delay reduction.
Determine annual dollar benefit:	From table 19 (DS-89/10, p. 152) for an 90/10 aircraft mix obtain $5,061 delay cost per hr. Multiply 0.42 hrs savings times $5,081 to yield $2,126 per yr.
Step 6 Calculations	
Determine 15-year life cycle benefit:	Multiply $2,126 per yr by 7.977 multiplier (DS-89/10, p. 152) to convert constant annual dollars to a 15-year life cycle to yield $16,959 15-year life-cycle benefit.
Determine benefit/cost ratio:	From appendix F, the cost of a rotorcraft intercept point is assumed to cost about the same as a LORAN-C non-precision approach, which is $32,179. The benefit/cost ratio is 0.53.

FIGURE C-7 ROTORCRAFT INTERCEPT POINT AT A CONGESTED AIRPORT - BENEFIT 10 (DS-89/10, p. 155) (Continued)

Assumptions:

Probability of the weather being below 1,000 feet ceiling and 1 mile visibility:	6.0%
Probability of the weather being below 466 feet ceiling and 3/4 mile visibility:	3.2%
Peak hours per year:	1,252 hours (DS-89/10, p. 148)
Fixed-wing annual instrument operations:	120,000 operations per year
Helicopter annual instrument operations:	3,000 operations per year
Annual growth rate for all operations:	0% annual growth
Ratio of air transport to general aviation operations:	60% air transport/40% general aviation

Step 1 Calculations (DS-89/10, p. 156)

Percent of time weather is between 466 ft and 3/4 mile and 1,000 ft and 1 mile:	6.0% - 3.2% = 2.8%
IFR peak hours per year:	(1,252 hours)*2.8% = 35 IFR peak hours/yr

Step 2 Calculations

From table 16 (DS-89/10, p. 149), find fixed-wing IFR peak hour operations:	Entering table 16 with 120,000 annual instrument operations yields 54 IFR peak hour ops without rotorcraft.
Determine rotorcraft IFR ops/peak hour:	3,000 rcft ops/yr * 30% in peak hr/ 1,252 peak hr = 0.72 rcft IFR peak hr ops
Determine rotorcraft IFR approaches/ peak hour:	0.72 IFR ops/peak hr * 50% = 0.36 IFR approaches/peak hr

Step 3 Calculations

Determine delay without reduced separation from equation E-1 in appendix E:	From table E.1, the ultimate capacity of a runway with a 60/40 mix is 72.12. Using a touchdown ratio of 1.43 from table E-3 yields 54 fixed-wing IFR ops/peak hr plus 0.36 rcft IFR peak hr approaches times 1.43 equals 54.515 ops per peak hr without applying reduced separation standards. Applying equation E-1 gives $(54.515/72.12)^2/(1 - 54.515/72.12) = 2.341$ hrs of delay per peak hr.

FIGURE C-8 THE BENEFIT FOR REDUCING APPROACH SEPARATION TO 2.5 MILES - BENEFIT 11 (DS-89/10, p. 155)

Determine delay with reduced separation from equation E-1:	Using a touchdown ratio of 1.27 from table E-5 yields 54 fixed-wing IFR ops/peak hr plus 0.36 rcft IFR peak hr approaches times 1.27 touchdown ratio equals 54.457 ops per peak hr with reduced separation standards. Applying equation E-1 gives: $(54.457/72.12)^2/(1 - 54.457/72.12) = 2.328$ hrs of delay per peak hr.
Step 4 Calculations	
Determine delay reduction with use of 2.5 mile separation:	2.341 hrs of delay without reduced separation minus 2.328 hrs of delay with reduced separation yields 0.013 hrs of delay reduction per IFR peak hr.
Step 5 Calculations	
Determine annual IFR peak hour delay reduction:	0.013 hrs delay reduction/hr times 35 IFR peak hrs/yr equals 0.455 hrs of annual delay reduction.
Determine annual dollar benefit:	From table 19 (DS-89/10, p. 152) for a 60/40 aircraft mix obtain $3,459 delay cost per hr. Multiply 0.455 hrs savings times $3,459 to yield $1,574 per yr.
Step 6 Calculations	
Determine 15-year life-cycle benefit:	Multiply 1,574 dollars per yr by 7.977 multiplier (DS-89/10, p. 152) to convert constant annual dollars to a 15-year life cycle to yield $12,556 15-year life-cycle benefit.
Determine benefit/cost ratio:	The cost of implementing this change is small as only procedure development and ATC training changes are required.

FIGURE C-8 THE BENEFIT FOR REDUCING APPROACH SEPARATION TO 2.5 MILES - BENEFIT 11 (DS-89/10, p. 155) (Continued)

APPENDIX D
ESTIMATION OF INCREASED ROTORCRAFT OPERATIONS RESULTING FROM ATC IMPROVEMENTS

Certain types of ATC system improvements enable aircraft to operate during times when poor weather would preclude operations if those improvements were not in place. The most obvious example of such an improvement is a new or improved instrument approach capability. Without the new instrument approach capability, aircraft operations at an airport or heliport cannot be performed when the weather is below the minimums of the current landing system. However, when the airport or heliport has a new instrument approach capability, additional operations can be performed by suitably equipped aircraft flown by qualified pilots.

In such instances, the operations for the airport or heliport in question will be increased when the subject ATC system improvement is in place and operating. The following paragraphs develop a methodology for estimating the operations at an airport or heliport following the incorporation of an ATC system improvement that allows operations to lower weather minimums.

Definition of terms:

Let O_C = current operations at the facility without the ATC improvement;

O_I = estimated increased operations at the facility due to the ATC improvement;

O_N = estimated new operations count at the facility with the ATC improvement;

P_C = percent of time that weather minimums at the facility are at or better than those required to operate without the ATC improvement;

P_I = percent of time that weather minimums at the facility are in the range that operations can be performed if the ATC improvement is in place; and

P_E = percent of aircraft that are equipped to operate using the ATC improvement.

Analysis:

If all aircraft using the facility would benefit from the ATC improvement, then the additional operations, O_I, would simply be the current operations, O_C, times the ratio of the time that the weather is in each range of minimums; i.e.,

$$O_I = O_C * P_I / P_C \qquad \text{Equation 1}$$

However, not all aircraft can use the ATC improvement so this ratio must be adjusted by the percent of suitably equipped aircraft, P_E, so that equation 1 becomes:

$$O_I = P_E * O_C * P_I / P_C \qquad \text{Equation 2}$$

The new operations count, O_N, is simply the sum of the current operations, O_C, plus the additional operations, O_I, enabled by the ATC improvement, which is:

$$O_N = O_C + O_I = O_C + (P_E * O_C * P_I / P_C)$$

$$= O_C * [1+(P_E * P_I/P_C)] \qquad \text{Equation 3}$$

Example:

To illustrate the application of equation 3, a numerical example is presented herein. For this illustration, assume heliport XYZ is considering the development of a nonprecision instrument approach using an existing VOR facility located at a nearby airport. Currently, XYZ has no instrument approach capability and has about 900 VFR operations per year. Operators using XYZ now land there when weather minimums are better than a 500 foot ceiling and 0.50 mile visibility, which is about 90 percent of the time. It is estimated that a rotorcraft nonprecision approach would have minimums of a 350 foot ceiling and 0.25 mile visibility. The weather is between 350 ft/0.25 mi. and 500 ft/0.50 mi. approximately 6 percent of the time. A high percentage (85 percent) of the helicopters using XYZ are IFR-certified, equipped with a suitable VOR, and are operated by IFR-qualified flight crews. What is the expected number of annual operations at XYZ if this instrument approach is developed?

O_C = 900 operations per year at XYZ heliport;

$P_C = 90\%$; $P_I = 6\%$; and $P_E = 85\%$.

From equation 3, the new annual operations count is estimated to be:

$$O_N = 900 * [1+(0.85 * 0.06/0.90)] = 951 \text{ operations/year.}$$

APPENDIX E

ENHANCEMENTS TO THE ROTORCRAFT PROCEDURAL BENEFITS METHODOLOGY

E.1 INTRODUCTION

The background and concept for determining rotorcraft procedural benefits are presented in sections 8.3.5 and 8.3.6 of reference 14. Further analyses applying the methodologies of these sections has shown that some enhancements to the methodology should be made to the delay model represented by tables 17 and 18 in reference 14. This appendix describes these enhancements.

E.2 BACKGROUND

The basic concern with the methodology of reference 14 stems from the use of table 17 when hourly operation rates on a runway approach the runway capacity. The data used to build table 17 come from reference 29, figure 3. These data present total delay as a function of runway operations per hour for four mixes of air carrier/general aviation aircraft and four separation criteria. In figure 3, reference 29, the operation rates for the 3 nm. separation criteria, which represents busy terminal area operations, do not represent a stressed condition in which the runway is operating at or near capacity. For instance, the maximum operation rate was 30 operations per hour, while the runway capacity varied between 64 and 80 operations per hour depending on the traffic mix.

In reference 14, the approach used to determine the delay function was to use regression analysis to fit an exponential curve to the data points of reference 29, figure 3. The resulting curve is quite satisfactory over the range of data points used to generate the model (up to 30 operations per hour). However, beyond these points, the validity of the regression curve is somewhat suspect.

E.3 QUEUING THEORY MODEL

Several methodologies were investigated in an attempt to overcome the limitations of the data in figure 3 of reference 29. The methodology that was selected makes use of a theoretical basis from queuing theory, and makes a comparison of the results with all of the data in figure 3, reference 29, not just the 3 nm. separation data.

Reference 30 addresses runway capacity and delay modeling. Mathematical models for arrival and departure delay, based on steady-state queuing theory, are presented. These models are as follows:

$$D_A = \frac{R_A(SD_A^2 + 1/SR_A^2)}{2(1-R_A/SR_A)}$$

where D_A = mean delay to arriving aircraft, in time units (e.g. minutes per aircraft),

R_A = mean arrival rate, aircraft per unit time,

SR_A = mean service rate for arrivals, aircraft per unit of time or reciprocal of mean service time,

SD_A = standard deviation of mean service time of arriving aircraft.

similarly,
$$D_D = \frac{R_D(SD_D^2 + 1/SR_D^2)}{2(1-R_D/SR_D)}$$

where D_D = mean delay to departing aircraft, in time units (e.g. minutes per aircraft),

R_D = mean departure rate, aircraft per unit time,

SR_D = mean service rate for departures, aircraft per unit of time or reciprocal of mean service time,

SD_D = standard deviation of mean service time of departing aircraft.

For simplicity, a number of assumptions were made in implementing these models. They are:

- a mixed operation of arrivals and departures is operating on the runway,
- the statistical parameters for arrivals and departures are approximately equal,
- the standard deviation of the mean service time is small compared to the reciprocal mean service rate. Because this term is squared in the equation, it is negligible when compared to the square of the reciprocal mean service rate. Therefore, the standard deviation term can be neglected in the equation (e.g., a standard deviation that is 10 percent of the reciprocal mean service rate, contributes only 1 percent error when it is neglected), and
- the total delay for the runway can be estimated by multiplying the mean delay per arriving or departing aircraft by the mean arrival or departure rate, respectively.

The delay models then become:

$$\text{Total arrival delay} = R_A D_A = \frac{R_A^2 / SR_A^2}{2(1-R_A/SR_A)}$$

$$\text{Total departure delay} = R_D D_D = \frac{R_D^2 / SR_D^2}{2(1-R_D/SR_D)}$$

Since the arrival and departure statistics are assumed to be approximately equal, the total delay is the sum of the total arrival delay and the total departure delay. The resulting total delay can be written:

$$\text{Total delay} = D_T = \frac{R_T^2 / SR_T^2}{(1-R_T/SR_T)} \qquad \text{Equation (E-1)}$$

where D_T = total delay for all aircraft per unit of time (e.g., hours of delay per hour of operation),

R_T = operation rate for the runway (e.g., operations per hour), and

SR_T = mean service rate or ultimate capacity for the runway.

E.4 ULTIMATE RUNWAY CAPACITY

A simplified model of the statistic describing ultimate runway capacity was developed from the aircraft separation distance, the aircraft approach speed, and the percentage air carrier and general aviation aircraft mix. This model is:

$$uc = \frac{2}{pa*ds/va + pg*ds/vg}$$

where uc = ultimate runway capacity in operations per hour (arrivals and departures, which accounts for the factor of 2 in the equation),

ds = aircraft separation distance in nm.,

va = air carrier aircraft approach speed (125 knots),

vg = general aviation aircraft approach speed (90 knots),

pa = percentage of air carrier operations on the runway, and

pg = percentage of general aviation operations on the runway.

Ultimate capacity values used for the comparison of the delay model with table 3 of reference 29 are presented in table E.1.

TABLE E.1 ULTIMATE RUNWAY CAPACITIES

AIRCRAFT SEPARATION DISTANCE (nm)	ULTIMATE RUNWAY CAPACITY (Operations/hour)		
	90% AC/10% GA	80% AC/20% GA	60% AC/40% GA
3.0	80.21	77.32	72.12
7.5	32.09	30.93	28.85
10.0	24.06	23.20	21.63
15.0	16.04	15.46	14.42

E.5 COMPARISON OF MODEL WITH SIMULATION DATA

Using the ultimate runway capacity values in table E.1, the queuing theory delay model was compared with the delay data generated by simulation contained in figure 3 of reference 29. The results of this comparison are shown in figure E.1. The independent variable in the figure is the ratio of operation rate to ultimate capacity. The results show general agreement throughout the zero to unity range of

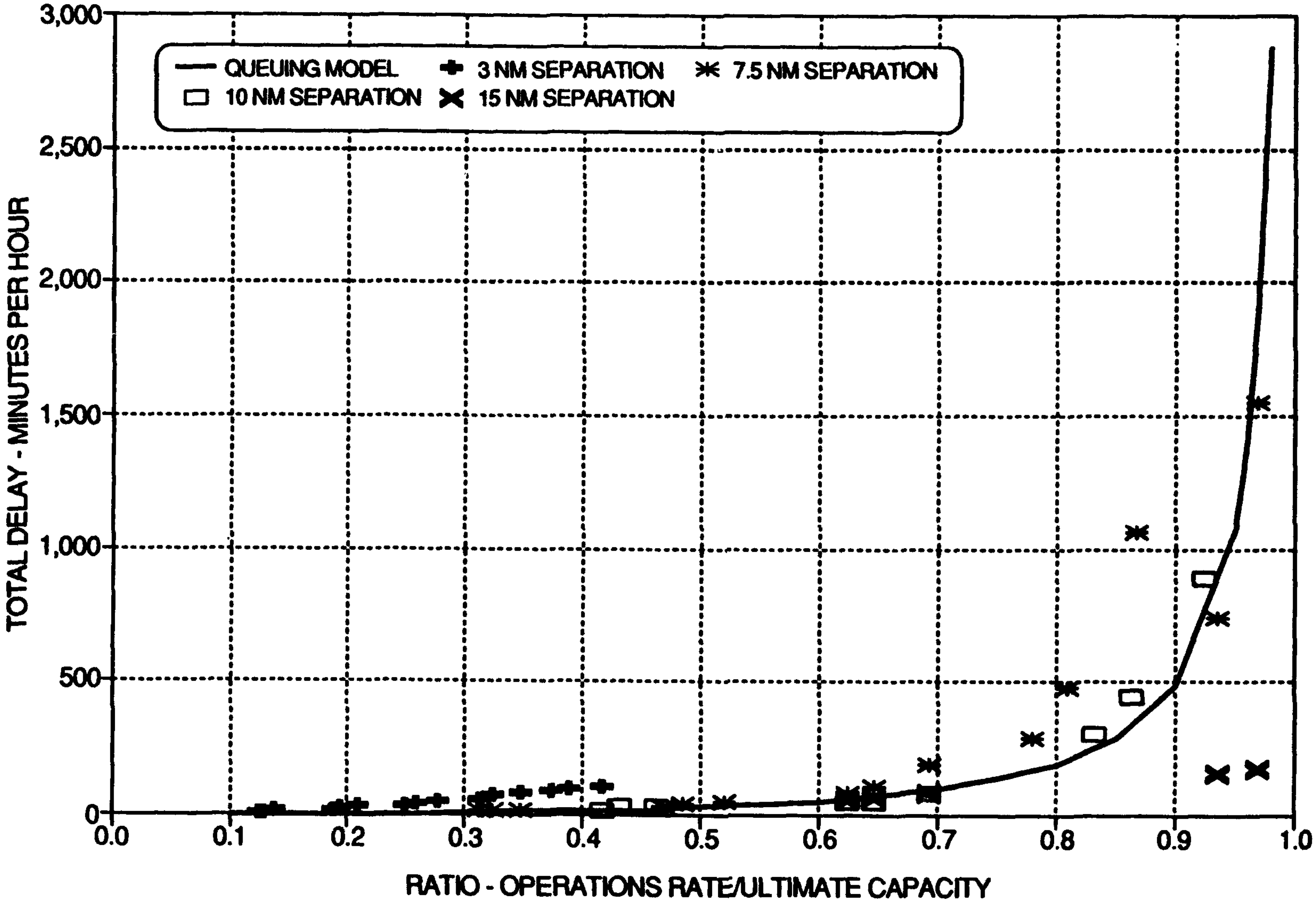


FIGURE E.1 COMPARISON OF QUEUING THEORY MODEL WITH SIMULATION DATA

the ratio. There is variation in the simulation data that can't be accounted for in a model as simplified as the queuing model. However, the model does conform to the general shape of the simulation data. The model is considered to be a conservative measure of runway delay as a function of the operation rate ratio and quite suitable for the purpose of estimating delay for the purpose of benefit/cost analysis.

Table E.2 is presented as an alternative to table 17 in reference 14. The delay values in table E.2 are more representative values of delay over the entire range of operation rates than the delay values in table 17.

E.6 TOUCHDOWN RATIO ENHANCEMENTS

In reference 14, table 18 presents values for touchdown ratios that are used in the rotorcraft procedural benefit calculations. The touchdown ratio is the ratio of average operation rates on a runway with rotorcraft to average operation rates without rotorcraft. The following assumptions apply to this analysis:

- o air carrier (AC) approach speed is 125 knots,
- o general aviation (GA) approach speed is 90 knots,
- o rotorcraft approach speed is 90 knots,
- o an air carrier aircraft following another air carrier aircraft maintains a 3 nm. separation throughout the approach,
- o a general aviation aircraft following another general aviation aircraft maintains a 3 nm. separation throughout the approach,
- o an air carrier aircraft following a general aviation aircraft will have a 3 nm. separation when the general aviation aircraft touches down on the runway,
- o all aircraft will intercept the final approach course outside the outer marker at a distance of approximately 8 nm. from the runway approach end, and the following aircraft will be separated from the leading aircraft by 3 nm. at this point. Thus the following aircraft will be 11 nm. from the runway, and
- o departures will be interspersed with arrivals at the same rate as arrivals.

Using these assumptions the following landing time separations are calculated:

AC following an AC: 60 min/hr * 3 nm/125 kts = 1.44 min.

AC following a GA: 60 min/hr * 3 nm/125 kts = 1.44 min.

GA following an AC:
60 min/hr * (11 nm/90 kts - 8 nm/125 kts) = 3.49 min.

GA following a GA: 60 min/hr * 3 nm/90 kts = 2.00 min.

where AC is an air carrier aircraft and GA is a general aviation aircraft.

TABLE E.2
RELATIONSHIP BETWEEN DELAY TIME AND NUMBERS OF INSTRUMENT OPERATIONS
(from queuing model)

NUMBER OF OPERATIONS PER HOUR PER RUNWAY	TOTAL MINUTES OF DELAY PER HOUR		
	90% AC/10% GA	80% AC/20% GA	60% AC/40% GA
10	1.1	1.2	1.3
15	2.6	2.8	3.3
20	5.0	5.4	6.4
25	8.5	9.3	11.0
30	13.4	14.8	17.8
35	20.3	22.5	27.5
40	29.8	33.3	41.5
45	43.0	48.6	62.1
50	61.9	71.0	94.1
51	66.6	76.7	102.5
52	71.7	82.9	111.8
53	77.2	89.6	122.3
54	83.2	97.0	133.9
55	89.7	105.2	147.0
56	96.9	114.1	161.9
57	104.7	124.1	178.8
58	113.3	135.1	198.3
59	122.7	147.5	220.8
60	133.2	161.3	247.2
61	144.9	176.9	278.5
62	157.9	194.7	316.2
63	172.5	215.1	362.3
64	189.0	238.6	419.9
65	207.7	266.1	494.0
66	229.2	298.6	592.6
67	254.1	337.6	730.1
68	283.2	385.0	934.8
69	317.6	444.1	1,271.5
70	358.8	519.5	1,927.2
71	409.2	619.0	3,760.2
72	472.1	756.2	37,380.1
73	552.6	957.3	O/C
74	659.2	1,280.1	O/C
75	807.0	1,881.8	O/C
76	1,025.3	3,396.6	O/C
77	1,379.9	14,396.4	O/C
78	2,055.6	O/C	O/C
79	3,845.7	O/C	O/C
80	22,380.2	O/C	O/C
81	O/C	O/C	O/C

O/C = Over Capacity

The average landing time is calculated from these separation times multiplied by their probability of occurrence. The average landing time for mixed AC/GA operations is therefore:

$$T_L = pa*pa*1.44 + pa*pg*1.44 + pg*pa*3.49 + pg*pg*2.00$$

where T_L = the average landing time in minutes, and
pa and pg are the percentage of air carrier and general aviation operations, respectively.

The average landing rate, R_L, is the reciprocal of the average landing time, T_L.

The landing times for rotorcraft (RC) following AC and GA aircraft are:

RC following an AC:
60 min/hr * (11 nm/90 kts - 8 nm/125 kts) = 3.49 min.

RC following a GA: 60 min/hr * 3 nm/90 kts = 2.00 min.

The average landing time for rotorcraft following AC and GA aircraft, T_R, is:

$$T_R = pa*3.49 + pg*2.00$$

The touchdown ratio is defined as T_R / T_L.

E.7 TOUCHDOWN RATIOS FOR POINT-IN-SPACE APPROACHES

When a point-in-space approach (or non-precision approach) to a heliport or vertiport at the airport is developed at a busy airport, the rotorcraft can use this approach when the weather is better than the point-in-space minimums. If there is no point-in-space approach, rotorcraft are forced to use a precision approach to an instrumented runway. Therefore operations with the point-in-space procedure effectively take the rotorcraft away from the precision approach runway and the delay is calculated in this case as if there were no rotorcraft operations. (Effectively, in this case, the touchdown ratio is zero because the percentage of the time that a rotorcraft follows an AC or a GA on the precision approach is zero.)

When there is no point-in-space procedure, the touchdown ratio determined in section E.6 applies. Delays are calculated using the assumed operation rate added to the product of the touchdown ratio and the rotorcraft operation rate.

Touchdown ratios for the point-in-space procedure benefits calculations are presented in table E.3.

TABLE E.3 TOUCHDOWN RATIOS WITHOUT SPECIAL ROTORCRAFT PROCEDURES

LANDING TIMES (minutes/operation)	PERCENT AIR CARRIER/GENERAL AVIATION OPERATIONS		
	90/10	80/20	60/40
AC/GA	1.63	1.79	2.02
AC/GA FOLLOWED BY A ROTORCRAFT	3.34	3.19	2.90
TOUCHDOWN RATIO	2.05	1.78	1.43

E.8 TOUCHDOWN RATIOS FOR THE ROTORCRAFT INTERCEPT POINT PROCEDURE

For the rotorcraft intercept point procedure, the rotorcraft is inserted into the final approach stream when the preceding aircraft is at the final approach fix, on approximately 5 nm from the runway. The rotorcraft is separated from the preceding aircraft by 3 nm, and is therefore 8 nm from the runway. When this procedure is used, the landing time for a RC following an AC becomes:

RC following an AC:
60 min/hr*(8nm/90 kts - 5nm/125 kts) = 2.93 min

The time for RC following a GA remains 2.00 minutes. The average landing time for rotorcraft following AC and GA aircraft, T_R, becomes:

$$T_R = pa*2.93+pg*2.00$$

These average landing times and touchdown ratios are shown in table E.4.

TABLE E.4 TOUCHDOWN RATIOS WITH ROTORCRAFT INTERCEPT PROCEDURE

LANDING TIMES (minutes/operation)	PERCENT AIR CARRIER/GENERAL AVIATION OPERATIONS		
	90/10	80/20	60/40
AC/GA	1.63	1.79	2.02
AC/GA FOLLOWED BY A ROTORCRAFT	2.84	2.75	2.56
TOUCHDOWN RATIO	1.74	1.53	1.27

The rotorcraft will be flying the precision approach. Therefore, this approach procedure is useful from VFR approach minimums down to precision approach minimums.

Benefits are derived by calculating the delays incurred without using the rotorcraft intercept point procedure and subtracting the delays incurred while using the procedure. To calculate delays without using the procedure, the touchdown ratio values in table E.3 are used. When calculating delays while using the procedure, touchdown ratios from table E.4 are used.

E.9 TOUCHDOWN RATIOS FOR REDUCED ROTORCRAFT SEPARATION PROCEDURE

For the reduced rotorcraft separation procedure, the separation for a rotorcraft following either an AC or a GA aircraft is reduced to 2.5 nm from 3.0 nm. This separation policy change, if proven feasible and safe, would reduce the landing times of rotorcraft following both AC and GA aircraft. As the preceding aircraft intercepts the precision approach course at the assumed 8 nm, as discussed in section E.6, the rotorcraft is now only 10.5 nm from the runway, rather than 11 nm. The landing times for rotorcraft following an AC or GA aircraft become:

RC following an AC:
60 min/hr*(10.5nm/90 kts - 8nm/125 kts) = 3.16 min

RC following a GA:
60 min/hr*2.5nm/90 kts = 1.68 min

The average landing time for rotorcraft following AC and GA aircraft, T_R, becomes:

$$T_R = pa*3.16 + pg*1.68$$

These average landing times and touchdown ratios are shown in table E.5.

TABLE E.5 TOUCHDOWN RATIOS WITH REDUCED ROTORCRAFT SEPARATION PROCEDURE

LANDING TIMES (minutes/operation)	PERCENT AIR CARRIER/GENERAL AVIATION OPERATIONS		
	90/10	80/20	60/40
AC/GA	1.63	1.79	2.02
AC/GA FOLLOWED BY A ROTORCRAFT	3.01	2.86	2.56
TOUCHDOWN RATIO	1.85	1.60	1.27

For the reduced separation procedure the rotorcraft will be following the precision approach procedure. Therefore, this approach procedure is useful from VFR approach minimums down to precision approach minimums.

As with the rotorcraft intercept point procedure, benefits for the reduced separation procedure are derived by calculating delays incurred without using the procedure and subtracting delays incurred while using the procedure. To calculate delays without using the procedure, the touchdown ratio values in table E.3 are used. When calculating delays while using the procedure, touchdown ratios from table E.5 are used.

APPENDIX F
ASR-9 AND LORAN-C APPROACH COST ANALYSIS

Costs for most of the ATC system improvements are taken from reference 14, appendix B. Since reference 14 was published, the costs associated with two ATC system improvements need to be updated. These systems are the airport surveillance radar (ASR), specifically the ASR-9, and LORAN-C nonprecision approaches.

F.1 ASR-9 COST ANALYSIS

The latest "Cost-Benefit Analysis of Provision of (Second Primary) ASR-9 Radar at Major Terminal Radar Approach Control Facilities," dated November 1992, reports that the present value cost of a new ASR-9 varies with location from $15.8M to $23.3M in 1990 dollars. These estimates include non-recurring costs based on ANR-120 Program Office estimates. These estimates include the ASR-9 hardware, beacon costs where applicable, automation hardware, physical plant for new sites, test equipment, spare parts, and program management.

These estimates also include recurring costs such as staffing, training, spares and rent, utilities, and other costs. Estimates for recurring costs are based on FAA standards and orders.

An ASR-9 life-cycle cost of $16.0M was selected for use in this report. The referenced report contains costs for three ASR-9 installations. Two of the costs are in the $16.0M range while one is significantly higher. Without detailed site information, it is difficult to determine life-cycle costs precisely. Therefore, the median cost of $16.0M was selected for use.

This cost data is more accurate than, and replaces, the cost data presented in section B.6 of reference 14.

F.2 LORAN-C NONPRECISION APPROACH COST ANALYSIS

The costs associated with a LORAN-C nonprecision approach are for two items: 1) initial plate development and annual review, and 2) initial flight inspection and reinspection every 270 days. The costs for these items were provided by FAA AVN-230, the Flight Inspection Policy and Standards Branch of the FAA's Office of Aviation System Standards. These costs are shown in table F.1. Consistent with FAA policy, the costs have been discounted at 10 percent per year for 15 years to arrive at $32,179 as the present value cost of a LORAN-C nonprecision approach in 1990 dollars.

TABLE F.1 LORAN-C NONPRECISION APPROACH LIFE-CYCLE COSTS

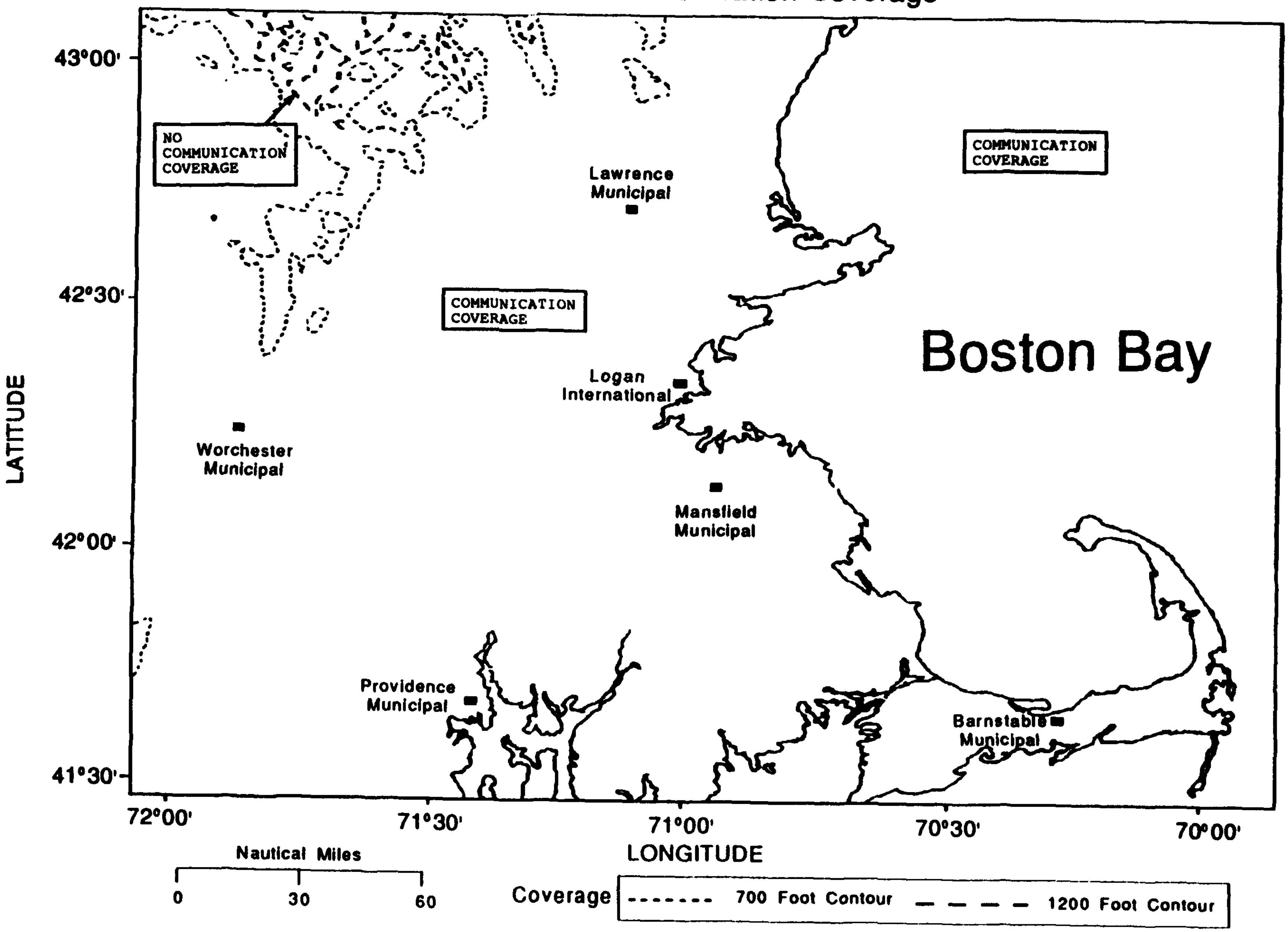
	1993 DOLLARS	1990 DOLLARS
Plate Cost	$1,310	$1,193
Annual Plate Update	$262	$239
Initial Flight Inspection	$5,564	$5,067
Reinspection Cost	$2,782	$2,534
Reinspection Cycle	270 Days	
1993 to 1990 Deflation Factor	1.098	

YEAR	DISCOUNT FACTOR	INITIAL PLATE	ANNUAL REVIEW	INITIAL FLIGHT INSPECTION	ANNUAL FLIGHT INSPECTION	ANNUAL COST	DISCOUNT COST	CUM DISCOUNT COST
1	0.9535	$1,193		$5,067	$845	$7,105	$6,774	$6,774
2	0.8668		$239		$3,378	$3,617	$3,135	$9,909
3	0.7880		$239		$3,378	$3,617	$2,850	$12,759
4	0.7164		$239		$3,378	$3,617	$2,591	$15,350
5	0.6512		$239		$3,378	$3,617	$2,355	$17,706
6	0.5920		$239		$3,378	$3,617	$2,141	$19,847
7	0.5382		$239		$3,378	$3,617	$1,947	$21,794
8	0.4893		$239		$3,378	$3,617	$1,770	$23,563
9	0.4448		$239		$3,378	$3,617	$1,609	$25,172
10	0.4044		$239		$3,378	$3,617	$1,463	$26,635
11	0.3676		$239		$3,378	$3,617	$1,330	$27,964
12	0.3342		$239		$3,378	$3,617	$1,209	$29,173
13	0.3038		$239		$3,378	$3,617	$1,099	$30,272
14	0.2762		$239		$3,378	$3,617	$999	$31,271
15	0.2511		$239		$3,378	$3,617	$908	$32,179
15-Year Life-Cycle Cost								$32,179

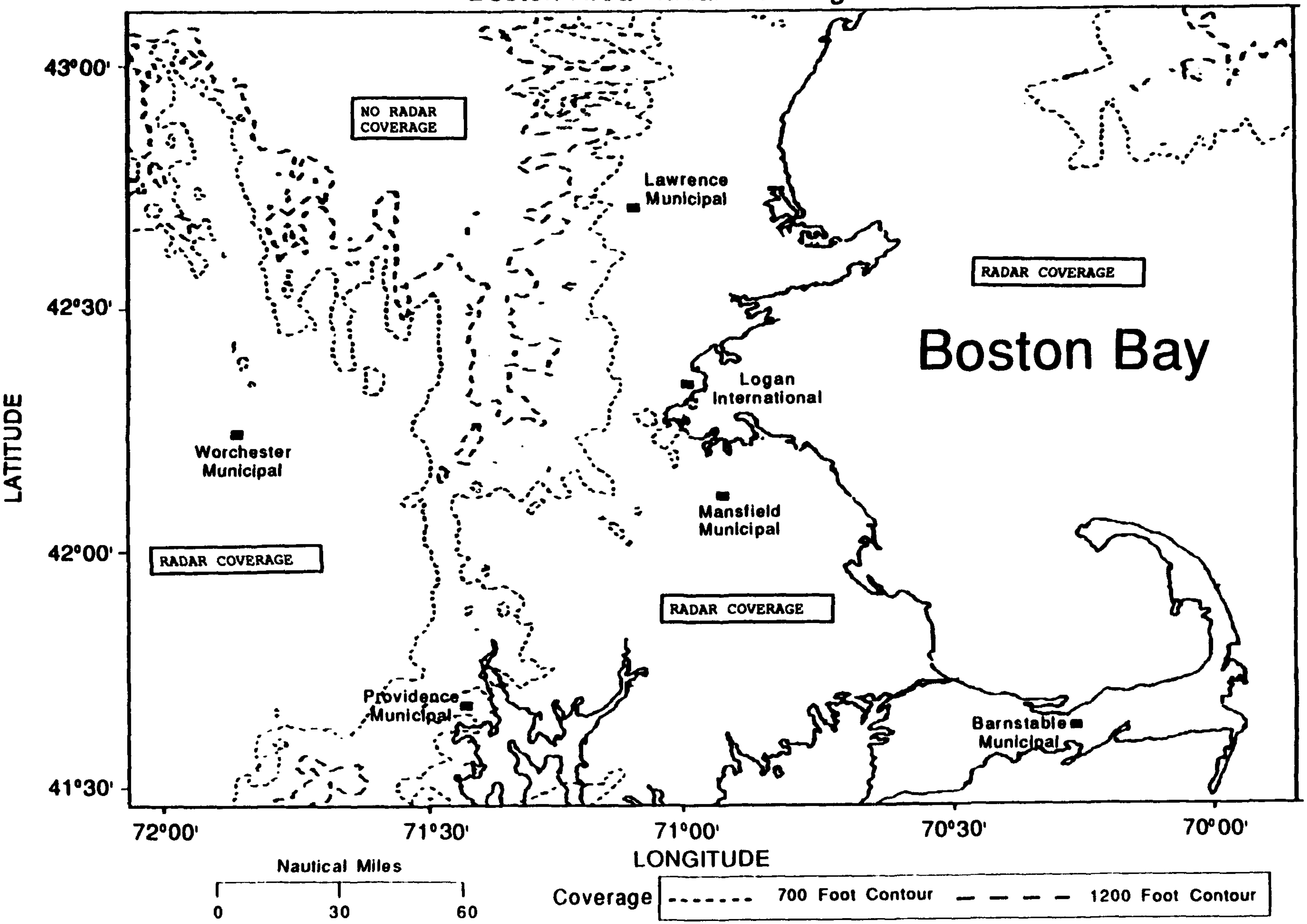
APPENDIX G
COMMUNICATIONS AND SURVEILLANCE COVERAGES OF SELECTED SITES

Communications and surveillance coverages for five different areas of the United States are presented in this appendix. The five sites depicted are: 1. Boston and vicinity, 2. Baltimore-Washington D.C. and vicinity, 3. New York City and vicinity, 4. Southern California, and 5. Southern Louisiana. All sites use tower en route control; therefore, only coverages from terminal communications and radar facilities are considered. These coverages include the effects on terrain only and exclude man-made obstructions.

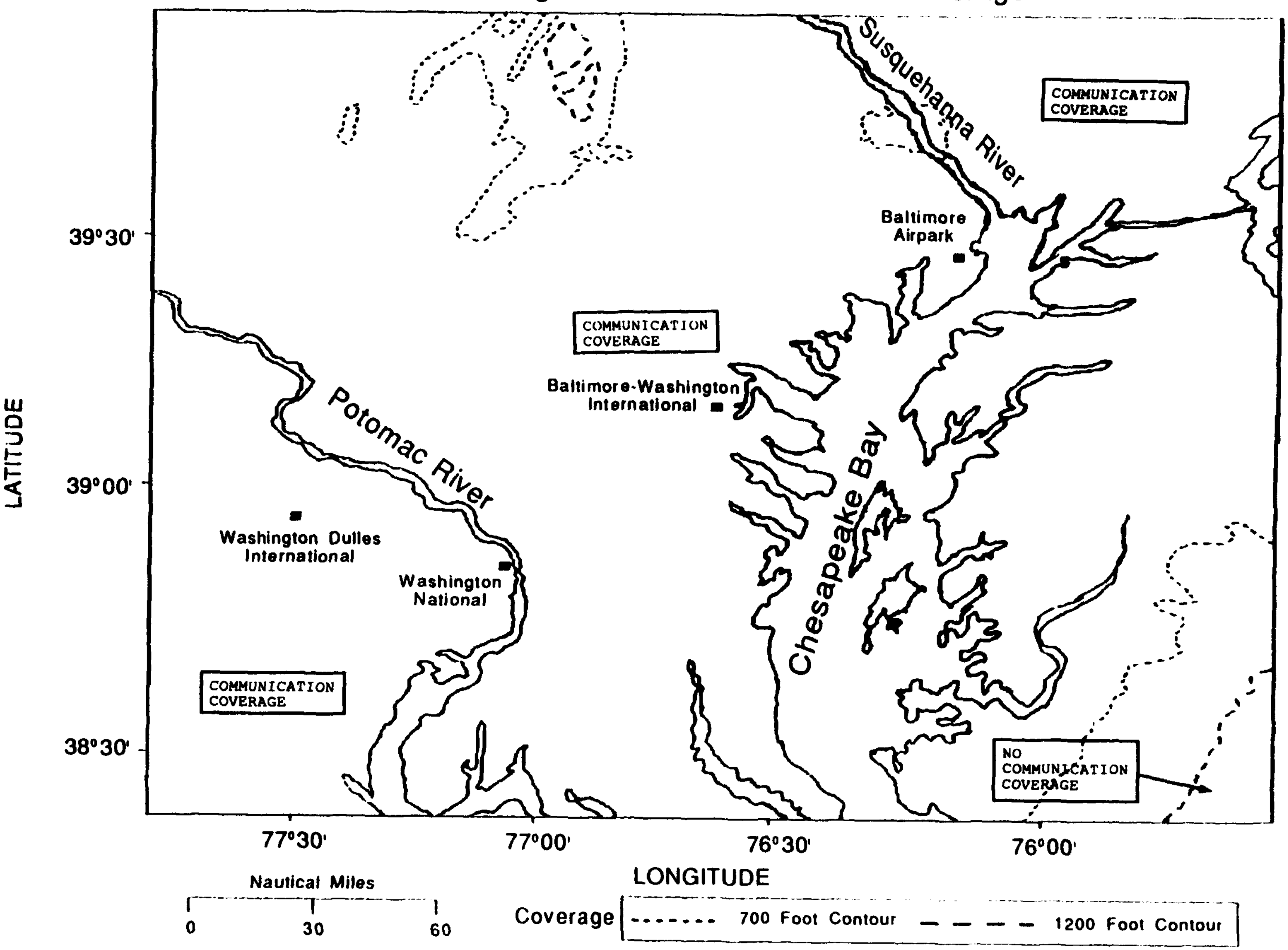
Boston Area Communication Coverage



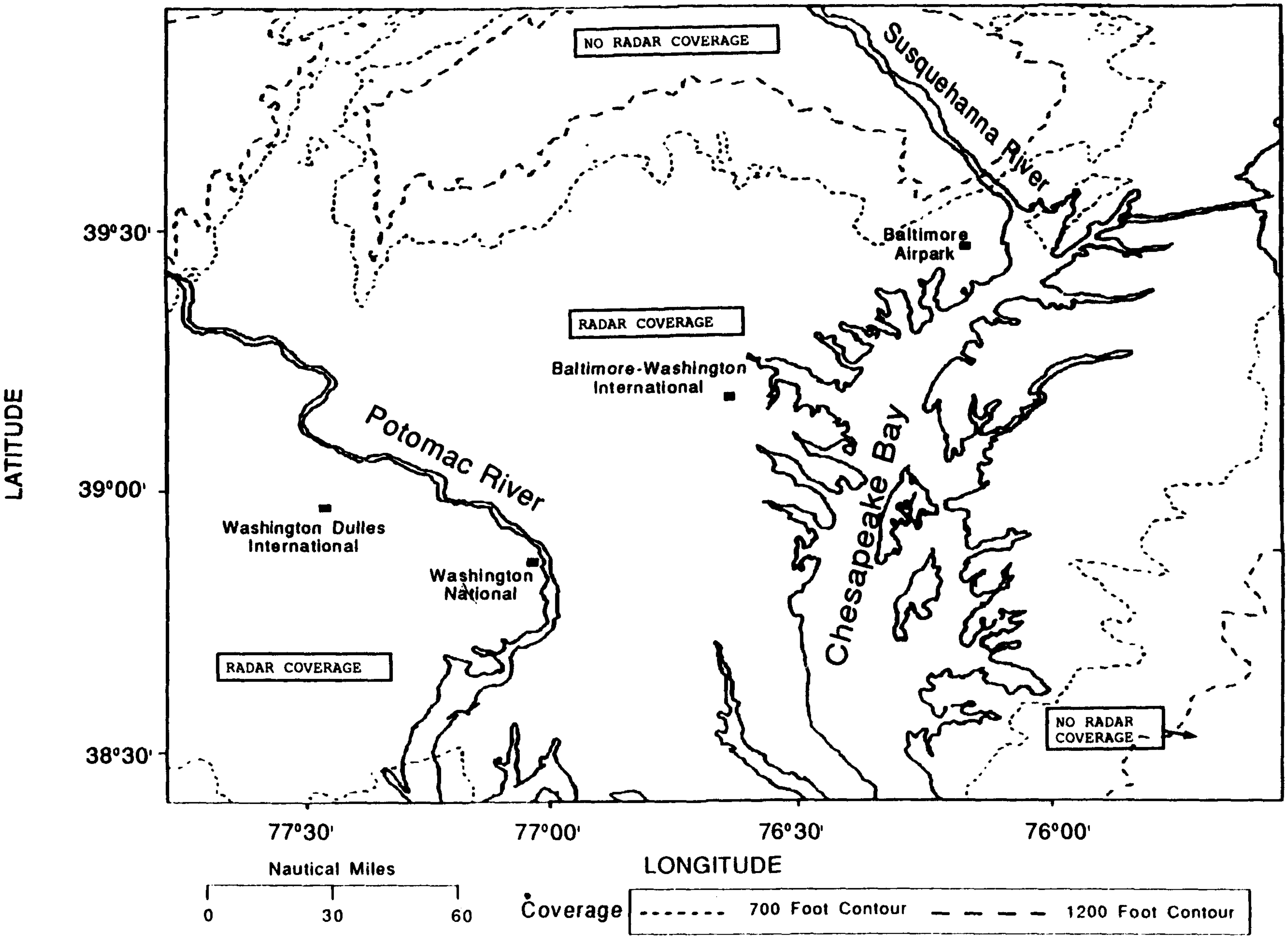
Boston Area Radar Coverage



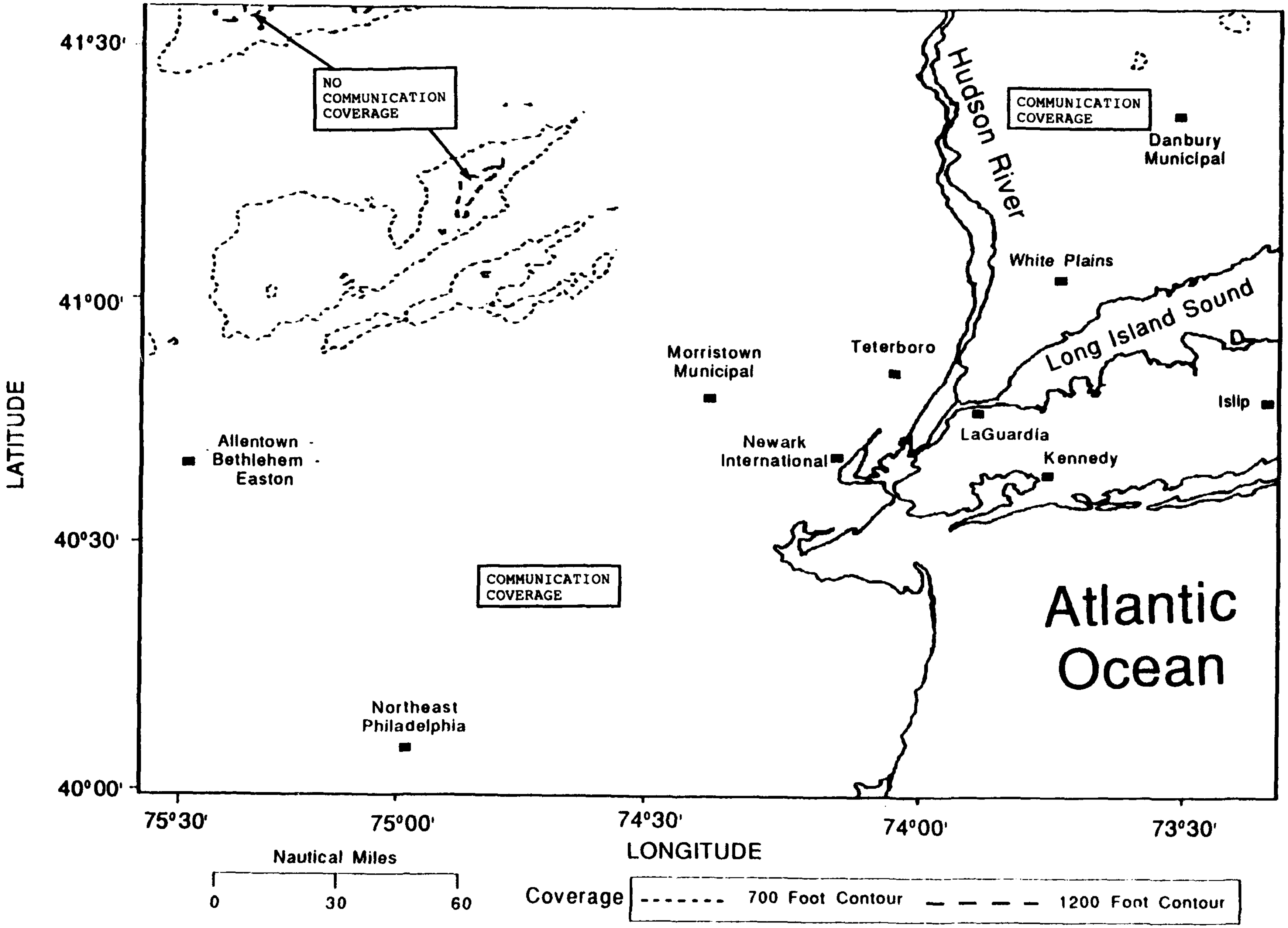
Baltimore-Washington Area Communication Coverage



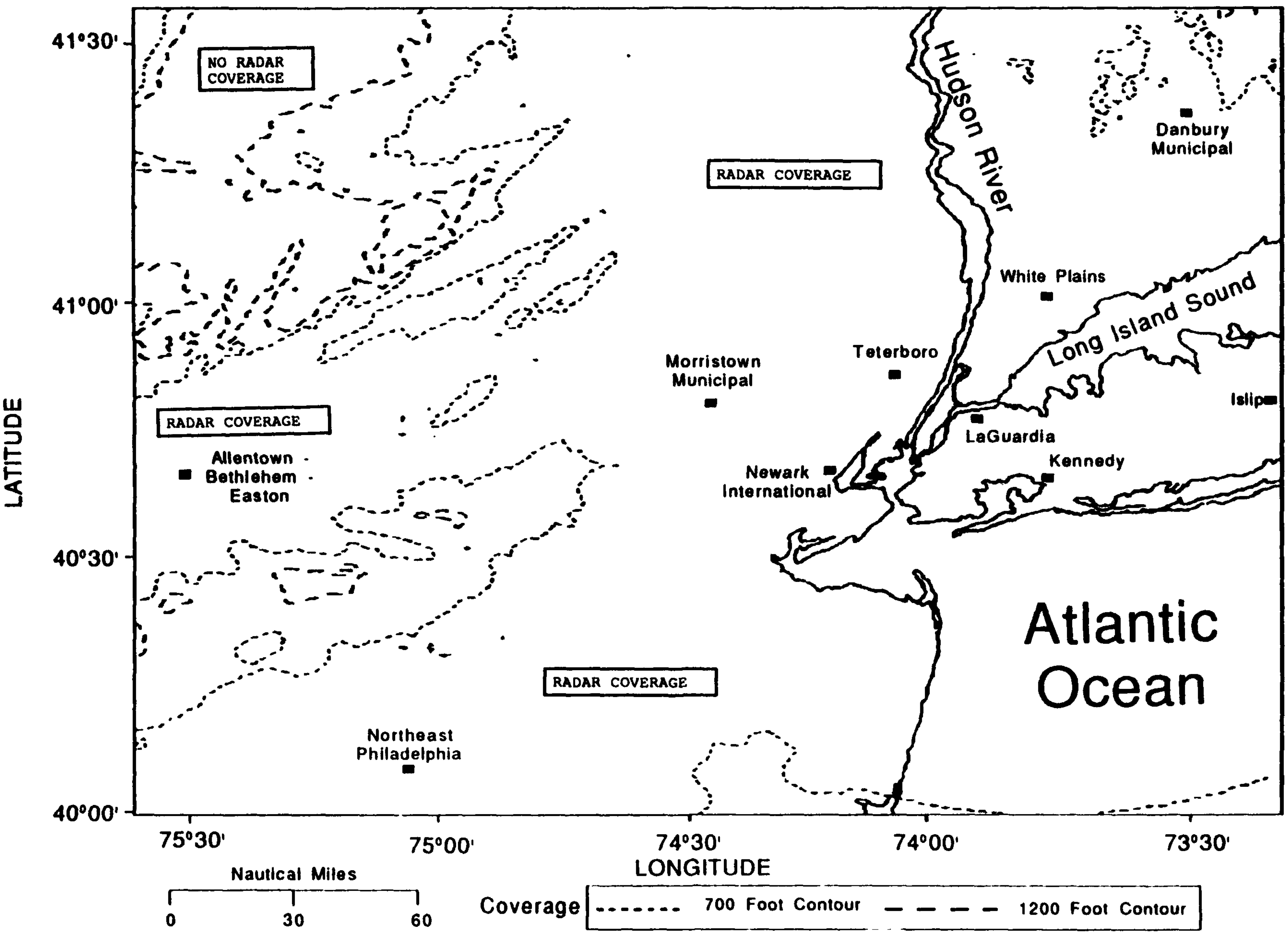
Baltimore-Washington Area Radar Coverage



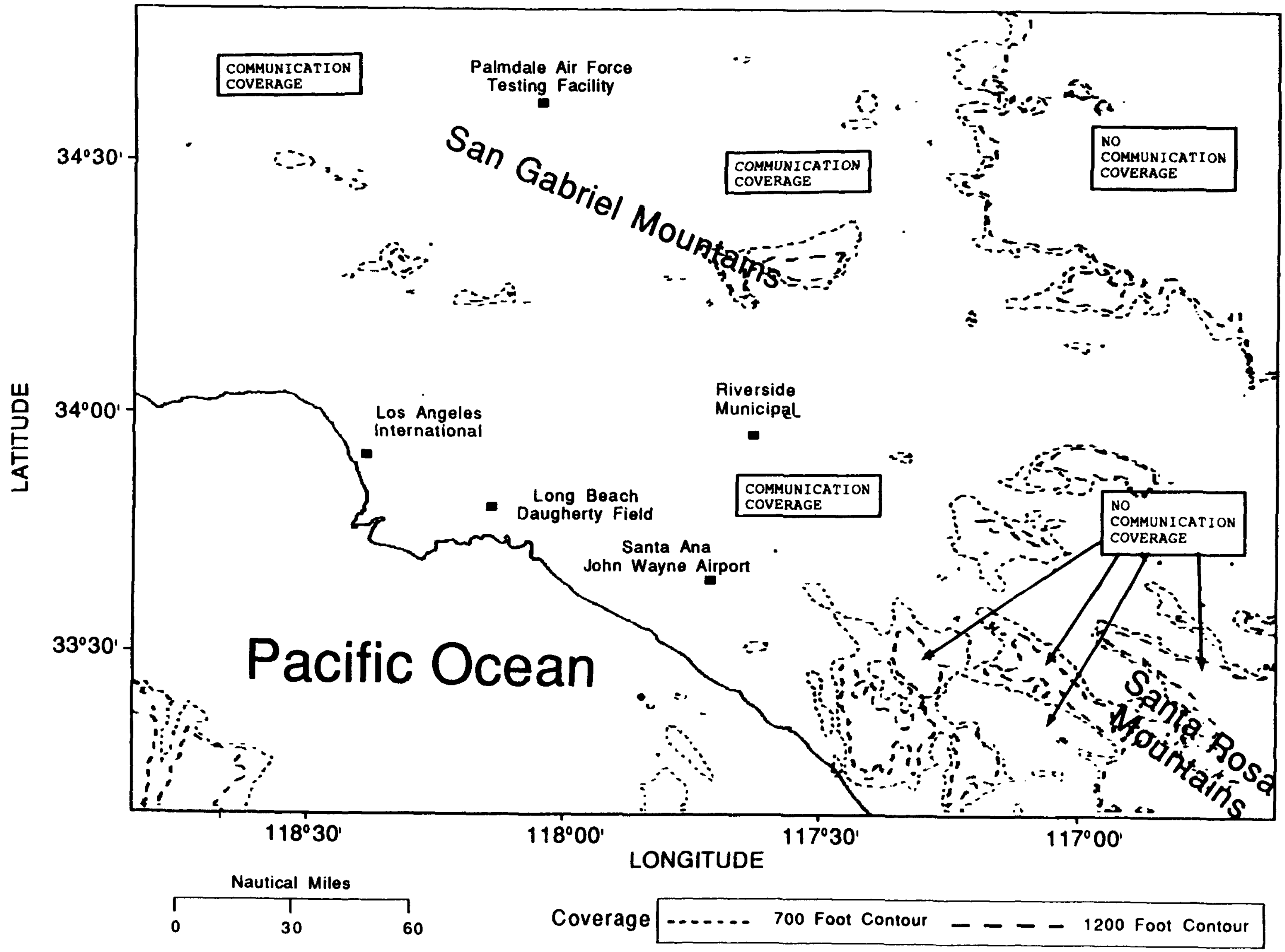
New York Area Communication Coverage



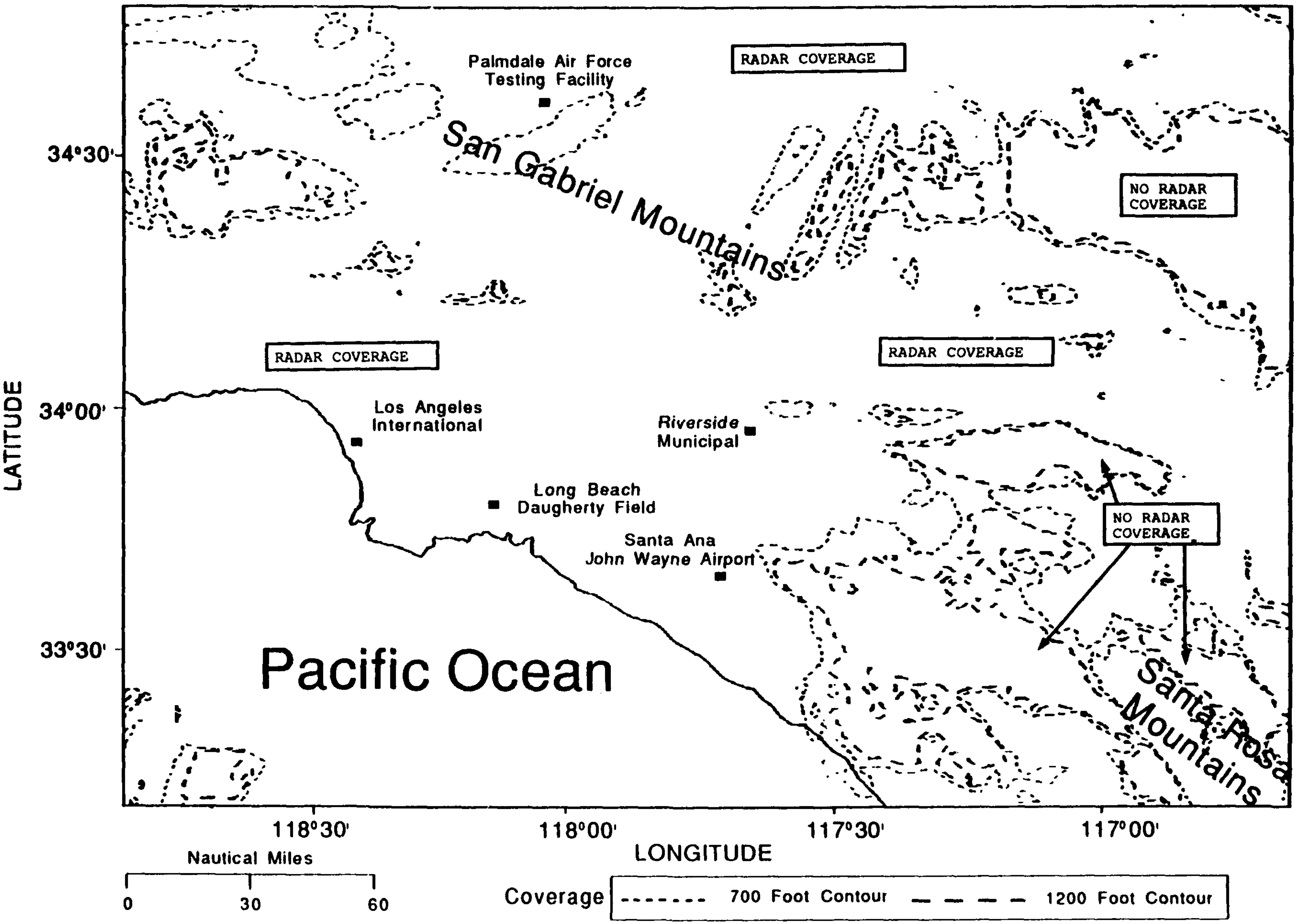
New York Area Radar Coverage



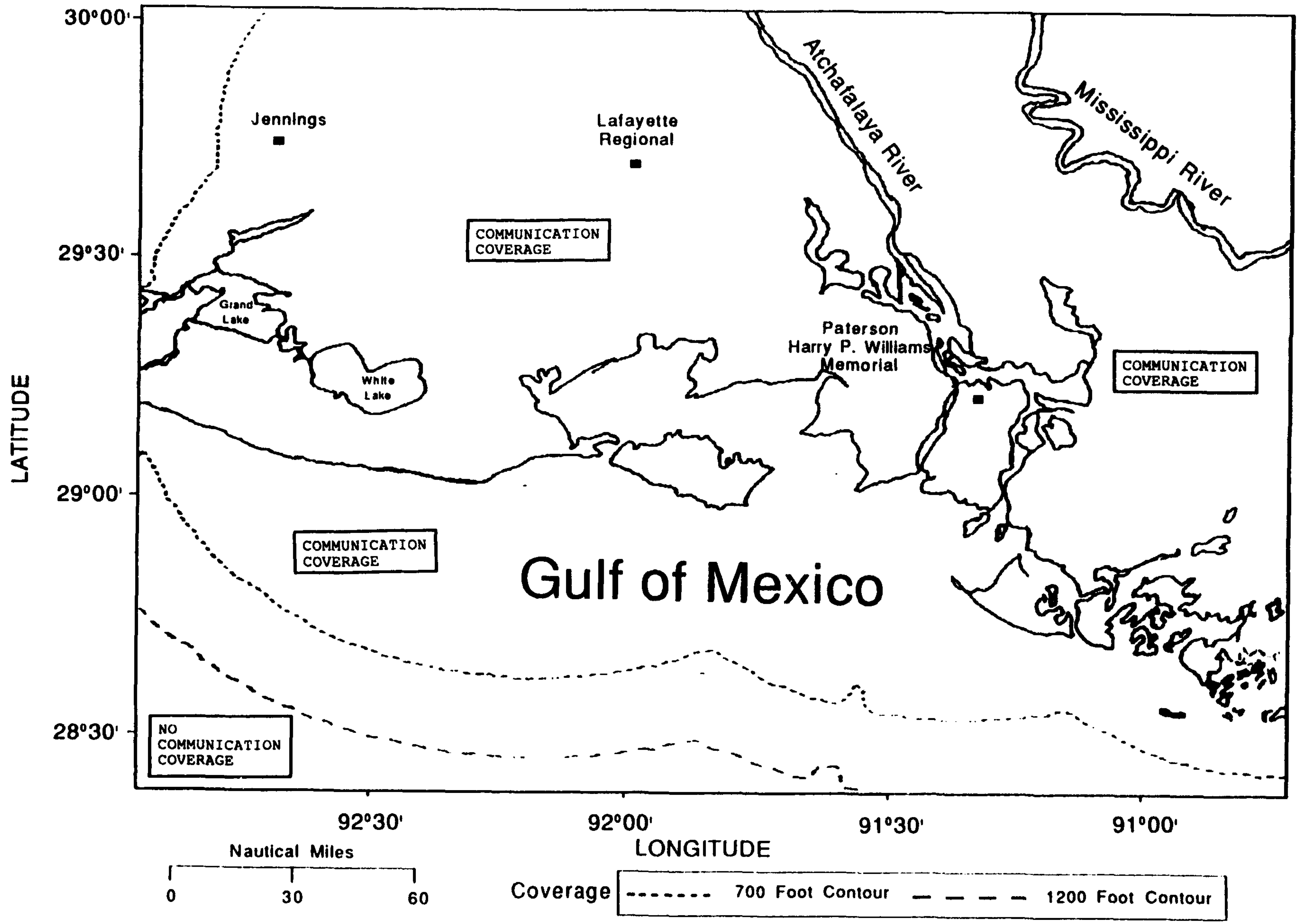
Southern California Communication Coverage

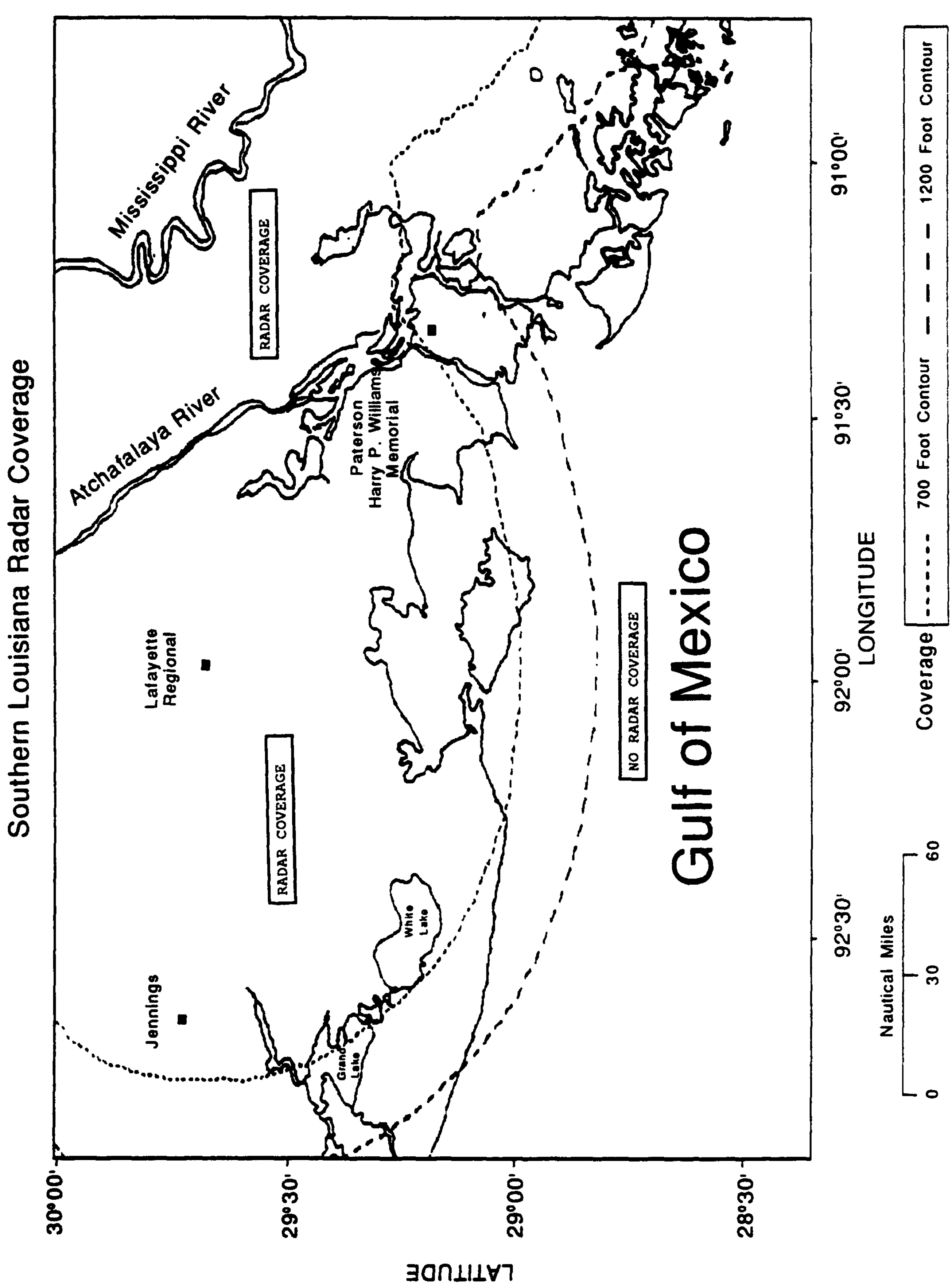


Southern California Radar Coverage



Southern Louisiana Communication Coverage





* U.S. G.P.O.:1993-301-717:80409